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1. Papers must be in a form suitable for publication and complete when communicated to the Society. They should be as concise as possible and accompanied by a brief abstract.

2. Papers should be double-spaced typescript on one side of the paper only. Ample margins, left and right, should be provided. Footnotes are to be avoided.

3. The use of italics should be restricted to generic and specific names, foreign words, and titles of periodicals.

4. All references should be listed at the end of the paper and be arranged alphabetically under authors' names, e.g.—

FENNER, C., 1918. The physiography of the Werribee River area. *Proc. Roy Soc. Vict.* 31: 176-313.

The corresponding reference in the text should be Fenner (1918) or (Fenner 1918) according to the construction of the sentence.

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ARCHAEOLOGICAL EXCAVATIONS ON THE AIRE RIVER, OTWAY PENINSULA, VICTORIA

By D. J. MULVANEY

[Read 8 December 1960]

Abstract

Aboriginal occupation deposits were excavated in two small rock shelters, in dune limestone, near the mouth of the Aire River. Both sites were stratified to a depth of several feet, and a C14 age estimation upon charcoel from a depth of 6 ft gave an age estimation of 370 ± 45 years. B.P. Molluscan remains from all levels typify the area at the present time. Although the area is well known as a collecting ground for carefully shaped and trimmed artefacts, no similar artefacts were excavated. Over 2300 struck stone flakes testify to the poverty of stone craftsmanship. A distinction is drawn between recent aboriginal material culture and an earlier prehistoric phase of superior stoneworking tradition. The finds are related to those from eroded midden sites around the coast.

Introduction

This report describes excavations conducted during January 1960 in two small rock-shelters in the dune limestone which fringes the coast of the Otway Peninsula, W. of the mouth of the Aire R. The Otway Peninsula is probably the least known Victorian tribal area, as 19th century records are virtually silent concerning its aboriginal inhabitants. However, for over half a century, collectors of stone implements have made rich finds of aboriginal artefacts on eroded surfaces, notably in the areas E. of the Cape Otway lighthouse and adjacent to the mouth of the Aire R. (cf. Mitchell 1949: 151-5). Their number and diversity of type testify to the relative intensity of prehistoric occupation. Indeed, environmental conditions in the southern peninsula, which projects into Bass Strait beyond the thickly forested Jurassic sandstone Otway ranges, must have favoured the aborigines. There was abundant fresh water. Occupation was facilitated by the occurrence of both shifting and consolidated dune ridges, rocky cliffs and boulder-strewn beaches, small lakes and marshy river flats, which ensured a wide variety of marine and aquatic food supplies and vegetation of varied utility. The timbered hinterland abounded in native animals.

Plentiful stone supplies were readily available in the beach shingle. Quartz pebbles and irregularly shaped nodules of flint are cast on the beach, either from submarine Tertiary beds, or exposures in the cliffs. [The geology of the area is described generally by Hall and Pritchard (1899) and Carter (1958).] Although this chert or flint is inferior to European supplies and possesses a deeply patinated cortex, it is easily flaked. The coastline from Cape Otway to beyond the South Australian border constitutes one of the rare sources of Australian flint. There is some evidence that it was a commodity valued for inter-tribal exchange over a wide area, but insufficient field work has been carried out to enable any definitive conclusion.

The rock-shelters both face the Otway ranges, allowing a superb vista across the river flats (Fig. 1). Shelter 1 is 165 yds from the Aire R. and almost 3 m. upstream from its mouth. The ocean is a mile away across the 300 ft high dune-limestone ridge, but the slope is steep and overgrown with brush, and the seaward side is edged with cliffs upwards of 200 ft in height. Easy access is available to the ocean beach at Castle Cove, 2 m. to the W., near the 'Glen Aire' station homestead.

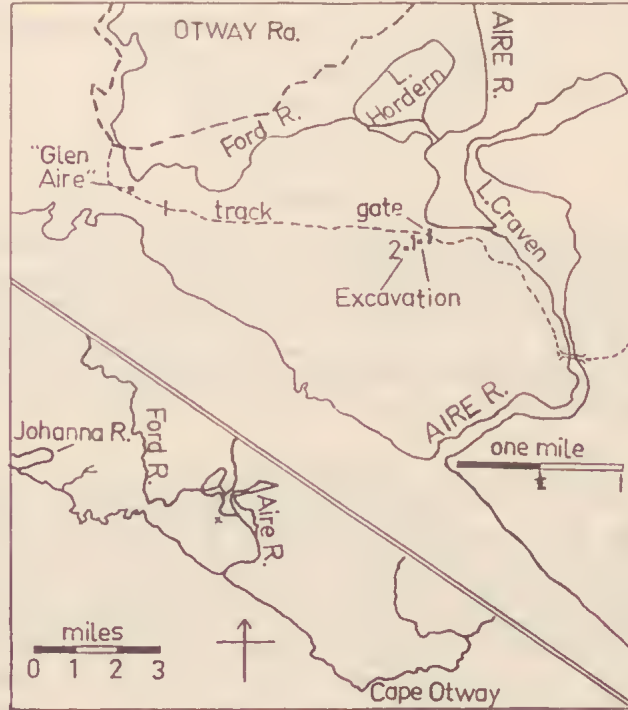


Fig. 1—Map of Aire River district.

In the absence of a detailed military survey map, it is difficult to supply a precise locality reference. In these circumstances, latitude and longitude ($38^{\circ}46'S.$, $143^{\circ}29'E.$) is only an approximation. Both sites are situated on Crown reserves. On the Victorian Lands Department map, Aire sheet, County of Polwarth, Shelter 1 is 44 yds W. of the SE. corner of Block 20 D. Shelter 2 is 79 yds W. of the same corner. Both sites are a few feet S. of the track which connects 'Glen Aire' with the bridge, a mile from the mouth of the Aire R. At present, a white gate across this track marks the relevant corner of Block 20 D.

The writer's attention was drawn to Shelter 1 by Mr Kingsley Sutton of Bal-larat, who visited the area on an implement collecting mission in company with Mr Donald Currie of Sydney. Australian prehistoric research has suffered through the attitude of those collectors who have concealed the location of valuable sites. In this case, however, in addition to admirable restraint in not investigating the site for themselves, the discoverers supplied precise instructions, enabling the writer and Mr D. A. Casey to visit the site and plan its excavation. On this preliminary survey, Shelter 2 was located, uphill from the other shelter, screened

behind a luxuriant boxthorn bush (*Lycium ferocissimum* Miers), a post-European plant introduction.

Aire Shelter 1

Unfortunately, most of the occupational deposit in Shelter 1 was removed some years ago. The material, chiefly shell and ash, had been scooped out by a front-end loader and used as filling for a track across marshy ground. As the plan (Fig. 2A) shows, the site was originally a large one, but only a narrow strip remained which clung tenuously to the rear wall. Natural erosion, rabbits and boxthorn roots had disturbed the remaining deposit which was exposed vertically for about 6 ft. The only practical course was to remove all the remaining deposit as a salvage measure.

Excavation demonstrated that the site was stratified and it is unfortunate that so much of it had been destroyed. Its area would have been far greater than was Shelter 2, but the remnant was so meagre that definitive conclusions were impossible. Immense numbers of marine shells, mixed with ash, occurred in superimposed layers or lenses, but the sharp outward curve of the rear wall, which became the basal floor at greater depth, meant that the lower layers were almost unrepresented (Pl. I). The large number of whole shells may indicate that molluscs were cooked, and the food extracted, without breaking the shell. The molluscan remains from both shelters are typical of the area at the present time and no significant variation of species was evident. The remains were predominantly the larger intertidal marine species, whose habitat is the rock-shelf, at and above mid-tide level; only a few freshwater mussels were present. Every species which was present in Shelter 1 was also identified from Shelter 2, and the list of remains is given there. Bone was uncommon and poorly preserved in the loose, dry sand and ash.

The deposit was divided into three layers, which have a stratigraphic basis, although it is not suggested that these relate to three distinct phases in the occupation of the site. The material recovered was negative in the extreme. Although 14 bone artefacts were present, not a single retouched stone flake was found among the 528 primary flakes and fragments.

LAYER 1

BONE ARTEFACTS: 1 fragmentary pointed bone, 3" in length.

STONE ARTEFACTS: 2 small quartz pebble hammer-stones; a large oval slab of dune limestone, apparently used as a lower millstone; 5 sandy limestone fragments, probably anvil-stones.

87 stone flakes, chips and cores were present; 68 were flint, 18 quartz and 1 chloritic sandstone.

LAYER 2

BONE ARTEFACTS: 1 flattened pointed bone, 2 $\frac{3}{4}$ " in length, broken at the other end; 2 bones, each c. 2" long, pointed at both ends and best described as muduks (fish gorges?): 2 round pointed bones, 1 $\frac{3}{4}$ " and 2" long—the base of each was ground obliquely across the diameter of the bone and rounded on the end, presumably a device to ensure a firm haft (Pl. IB, 4-5).

STONE ARTEFACTS: 7 quartz pebble hammer-stones; 5 flat water-worn limestone pebbles, which had been used for pounding and abrading, and 1 chloritic rock, possibly utilized as an anvil-stone; 1 small, oval flint core, subsequently utilized as a crude scraper. Flakes, and chip fragments num-

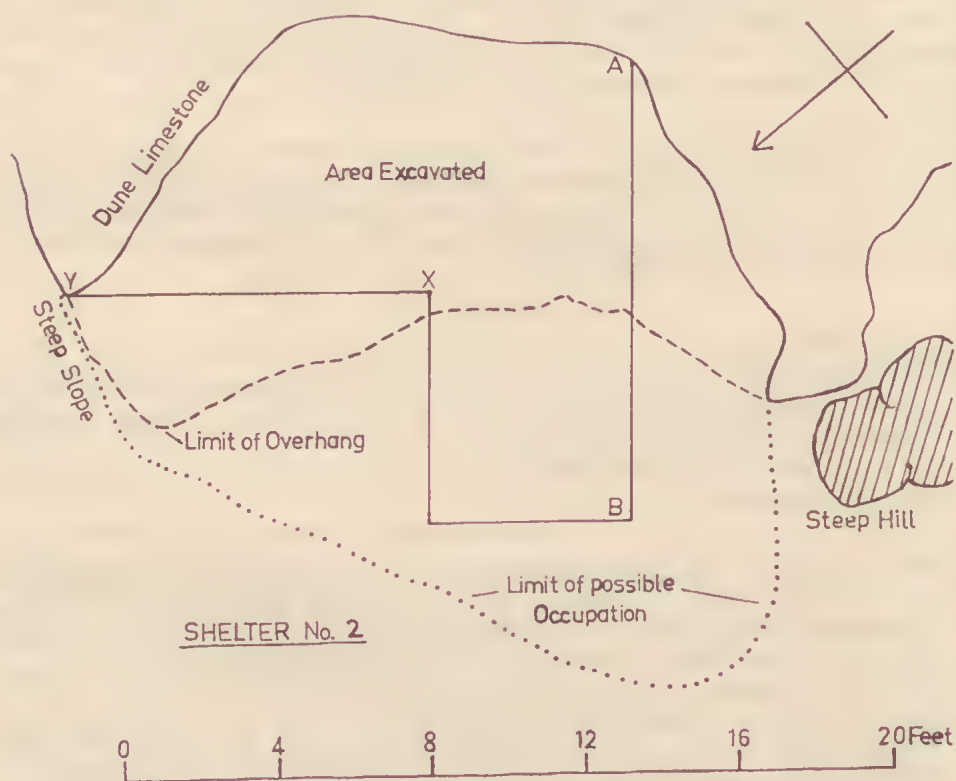
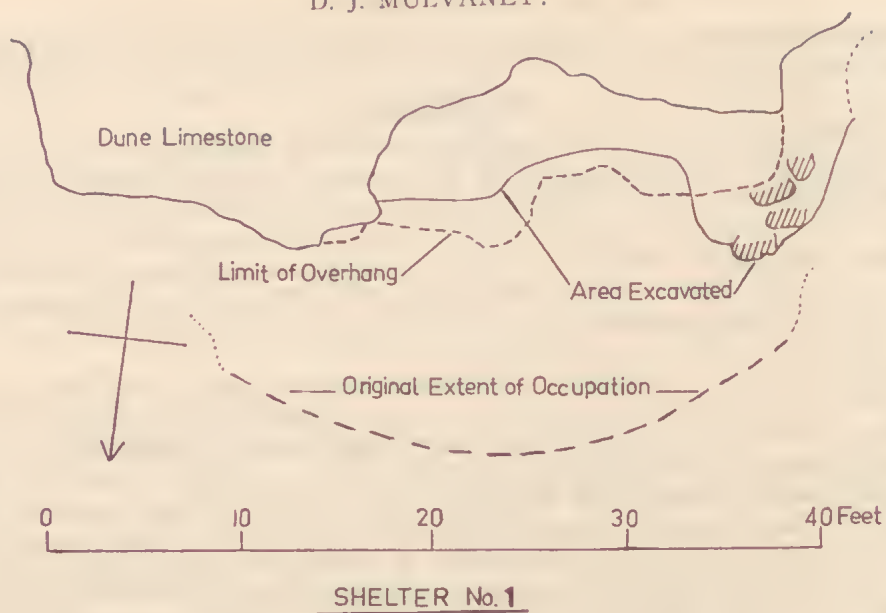


Fig. 2—A—Plan of Shelter 1; B—Plan of Shelter 2.

bered 195; 168 were flint, 23 quartz, 3 quartzite and 1 diabase. The small diabase fragment is similar to the diabase or epidiorite at Ceres, near Geelong.

LAYER 3

BONE ARTEFACTS: 7 points, ranging from $\frac{3}{4}$ " to 3" in length, made from split flat bones, ground to a point at one end; 1 thin round bone, $2\frac{1}{4}$ " long, tapering to a point, but in a poor state of preservation.

STONE ARTEFACTS: 7 quartz and 3 limestone pebble hammer-stones. There were 5 small red ferruginized silt-clay fragments which could have been utilized for decorative purposes. Flakes and other fragments totalled 242; 198 were flint, 40 quartz, 3 green chert pebble fragments, and 1 large rounded indeterminate basic rock fragment, possibly weathered basalt.

Aire Shelter 2

More positive results were obtained in the second shelter, most of which was excavated. The excavation could be extended further down the slope outside the shelter, but the steepness of the slope and the root systems of living vegetation would impede progress and limit the area of profitable study (Fig. 2B). The deposit was well stratified and had not been disturbed by burrowing animals. At the N. end of the shelter, traces of human occupation extended to a depth of almost 8 ft, although the lower horizons consisted simply of alternating bands of ashy black or clean yellow sand, and were free of artefacts, shells or bones. The deposit at the S. end was shallower than at the steeply-shelving N. end; however, it was intensively occupied. Charcoal from a depth of almost 6 ft in the centre of this shelter gave a radiocarbon 14 age estimation of 370 ± 45 years (Fig. 3).

LAYER 1

This was a deep, loosely packed accumulation of clean grey or yellow sand, most of which must have trickled down from the steep hillside above the S. end of the site. A thick carpet of dead grass covered the floor. During the preparatory removal of this rubbish, a worked bone artefact was found lying exposed on the surface beneath the plant cover. It was a point in a perfect state of preservation, clean and new in appearance. As no other evidence for human activity was uncovered until near the base of this stratum, it must be concluded that the accumulation of layer 1 began during the latest phase of aboriginal occupation, probably less than a century ago. The bone implement is best explained as one which was concealed in a cavity in the rock wall which was kept moist by seepage from above, and which only became dislodged during recent years. The point had close affinities with artefacts in layer 2.

BONE ARTEFACTS: The pointed bone mentioned above was made from solid bone, probably cut from a macropid limb-bone. It was highly polished, 3" in length and squared obliquely at the basal extremity. Numerous fine scratches were visible on most ground surfaces (Pl. IB, 1). 3 other utilized bones occurred near the base of this horizon—2 were thin bird-bones, 3" and $3\frac{1}{2}$ " in length, ground to needle-sharp points and the other was a thick bone, 3" long, deliberately flattened in section and tapered to a solid point at one end (Pl. III, 2-3, 12).

STONE ARTEFACTS: 1 large quartz pebble fragment and a smaller specimen of hornfels, which probably functioned as hammer-stones; 1 large fragment



Fig. 3—Vertical Sections of Shelter 2.

of an indeterminate basic rock is doubtfully classified as an anvil-stone. Flakes and fragments numbered 107; 104 were flint, 2 quartz and 1 was an indeterminate basic rock.

MOLLUSCS: *Austrocochlea constricta* (Lamk)—periwinkle; *Brachidontes rostratus* (Dunker)—mussel; *Cellana tramoserica* (Sowerby)—limpet; *Dicathais textilosa* (Lamk)—thaid; *Hipponyx conicus* (Sch.), *Lasaca australis* (Lamk)—small bivalve; *Poneroplax costatus* (Blainville)—chiton; *Scutus antipodes* (Montfort)—elephant snail; *Siphonaria diemenesis* Q and G., *Subnivalia undulata* (Solander)—turban shells; *Velesunio sp?*—fresh water mussel.

MAMMALS: *Trichosurus* sp. prob. *vulpecula*—possum; *Antechinus* sp. prob. *swainsonii*—phascogale; *Rattus lutreolus* (Gray), *Rattus assimilis* Gould; *Mastacomys fuscus* Thomas. Also present were 2 seal teeth, *Pinnipedia* prob. *Gypsophoca* sp. and indeterminate fragments of fish and bird bone.

LAYER 2

This stratum was fairly compact, deep grey and black in colour throughout, flecked with pieces of charcoal and numerous shells. These indications of intense occupation were supported by the number of stone flakes retrieved and the occurrence of 25 bone tools.

A human skeleton lay directly upon the firm surface of this horizon (Pl. II B). The sex was male and the age of death was around 25 years. The period of death must have been during the closing phases of aboriginal occupation as, stratigraphically, the remains related to the beginning of layer 1 times. Although the surviving bones were in a good state of preservation, there were unusual circumstances. No evidence of a grave was found; the bones were widely scattered, the pelvis and skull were together, while a humerus was found almost 2 ft from the nearest bone; the bones of the feet, hands and several vertebrae were absent; the extremities of most limb bones were eroded or marked. The most likely conclusion is that the person died in the shelter and that his body was disturbed by animals. It should not be classed as a burial. It could be urged that the body had been exposed and dessicated before its removal to the shelter, and it is relevant that Brough Smyth (1878: xxviii) recorded that 'on the swampy reed beds of the Aire River . . . are found even now the remains of the rude platforms on which the natives placed their dead'. However, the excavated remains differed from the characteristic tight bundle of reburied dessicated bones; nor is there evidence of respect for the deceased. A report, which the writer has been unable to confirm, states that the aborigines on the Aire R. were shot by native police, under the command of Foster Fyans, as a reprisal for their murder of a surveyor, near Blanket Bay around 1845. It is possible that these remains are those of a wounded survivor who crawled into this last refuge.

BONE ARTEFACTS: 8 carefully finished points, between 1½" and 4" in length, and a broken tip of another specimen. These artefacts show considerable variety of finish on the butt end, and fine scratches are visible on some of them. 2 specimens possibly were awls, while the remainder probably functioned as projectile-points (Pl. III, 1, 4-7). One specimen is fusiform, although only one end has a sharp point (Pl. III, 9). 16 fragments of split bone which had been either cut or ground to points were also recovered. Of interest were 2 fragments of split bone (one of which had been broken

in antiquity) which had deep grooves incised into them (Pl. I B, 2-3). The bones were probably limb bones of kangaroo and had been split lengthways; one bone was $\frac{1}{4}$ " thick. Presumably, both specimens represented attempts to remove a section of bone for reshaping into a point. The groove ran lengthways along the exterior surface of the bone and had been cut with a fine, sharp-edged implement which had been drawn along the bone on several occasions. In the absence of any evidence for burins or other secondary artefacts in the stone collection, it must be assumed that the bones were grooved with a primary flake of flint, many of which possessed keen edges.

STONE ARTEFACTS: 1 circular flint flake with traces of secondary retouch around the margin and therefore designated a scraper; 5 small flint flakes, not true scrapers, but possessing utilization fractures along the edges; 2 small flint cores; 8 pebbles of dune limestone and 1 of concretionary limestone, which possibly served as hammer-stones and anvil-stones; 1 quartz pebble hammer-stone. Flakes and other fragments numbered 1017, 1002 were flint, 12 quartz, 2 heavily ferruginized clay pebbles, and 1 fragment of basic calcareous sediment. There was one small fragment of red ochre.

MOLLUSCS: *Brachidontes rostratus* (Dunker), *Cabestana spengleri* (Perry), *Cellana tramoserica* (Sowerby), *Dicathais textilosa* (Lamk), *Haliotis ruber* Leach—mutton-fish; *Patellana peroni* (Blainville), *Poneroplax costatus* (Blainville), *Scutus antipodes* Montfort, *Subnivalia undulata* (Solander).

MAMMALS: *Thylogale billardieri* Desmarest, *Rattus assimilis* Gould, *Pseudocheirus peregrinus laniginosus* (Gould), *Macropodidae* (indeterminate).

Also present were indeterminate remains of bird, fish, 2 scal incisors (*Pinnipedia* prob. *Gypsophoca* sp.) and one large canine tooth of *Pinnipedia*, species indeterminate.

LAYER 3

This was a thick, grey horizon, rich in ash, which was subdivided into three for precision of record.

LAYER 3A

BONE ARTEFACTS: 1 spatulate-ended bone, broken at the other end; 1 pointed, round bone, $3\frac{1}{2}$ " long, broken at the basal extremity; 1 solid fusiform point, $2\frac{3}{4}$ " in length, of mudukian proportions (Pl. III); 1 fragment of highly burnished bird bone; 3 split bones, cut to sharp points.

STONE ARTEFACTS: 1 quartz pebble hammer-stone; 1 small dune limestone pebble anvil-stone, with a deep pit on one face; 1 irregular shaped tabular limestone fragment, probably a millstone; 2 dune limestone and 1 white concretionary limestone hammer-stones. Flakes and other fragments numbered 181, 169 were flint, 9 quartz, 1 quartzite, 1 rounded broken fragment of basic tuff and 1 of basic felspathic sediment. There were 2 small fragments of red ochre.

MOLLUSCS: *Brachidontes rostratus* (Dunker), *Cabestana spengleri* (Perry), *Cellana tramoserica* (Sowerby), *Chloritobadistes victoriae* (Cox)—land shell; *Dicathais textilosa* (Lamk), *Haliotis ruber* Leach, *Hipponyx conicus* (Sch.), *Kellia australia* (Lamk), *Lepsiella vinosa* (Lamk), *Melarapha prae-*

termisa (May)—periwinkle; *Poneroplax costatus* (Blainville), *Scutus antipodes* Montfort, *Subnivalia undulata* (Solander).

MAMMALS: *Rattus lutreolis* (Gray), macropid remains and indeterminate bone fragments.

Also present was parrot-fish: *Phargmogonathi*, Fam.: *Labridae*.

LAYER 3B

BONE ARTEFACTS: A point, 4" in length, broken at the basal extremity and tapering to a well-formed point at the other (Pl. III, 8); 1 round, fusiform bone, 3½" long, with an asymmetrical taper at one end (Pl. III, 10). Its function was probably as a projectile tip, although it may have been a nose-bone ornament; 1 symmetrical fusiform bone, 3" long, similar to the last specimen (Pl. III, 11); 4 simple pointed bones, ranging between 1¾" and 2¼" in length, of which two had been cut and the other two ground to points.

STONE ARTEFACTS: 2 limestone fragments, possibly anvil-stones or hammer-stones; 1 broken, edge-ground axe, 3" in diameter, 1" in thickness, of which only 2" at the blade-end survives. This is a classic Windang-type axe-head (McCarthy 1946: 47), made from a split pebble of albitized trachyte. One side of the blade preserves the original smooth pebble surface, while the other surface has been lightly ground, although there was little attempt to produce a sharp cutting-edge. This discovery is of some interest. It is one of the few Australian edge-ground axes whose stratigraphic position is known, and it is made from an unusual rock. Similar rocks are unknown in the Otway area. Trachytic rocks occur at Macedon and Woodend, but they are not recorded as affected by albitization. Victorian albite rocks are chiefly of Cambrian origin, but no trachytes have been recorded of Cambrian age. At present, therefore, the source of this stone is unknown, but it must lie beyond the Otway region.

Flakes and other fragments numbered 129, 108 were flint, 14 quartz, 2 limestone, 1 sandstone, 1 quartzite, 1 albitized trachyte and 2 tabular fragments of felspathic sediment. There was 1 minute fragment of reddish-brown ochre.

MOLLUSCS: *Brachidontes rostratus* (Dunker), *Halotis ruber* Leach, *Scutus antipodes* Montfort, *Subnivalia undulata* (Solander), *Vesunio ambiguus* (Philippi).

LAYER 3C

BONE ARTEFACTS: 5 small points made from split bone, 2 of which were subsequently ground; 1 thin, fusiform bone, 3¼" in length, which had been artificially flattened.

STONE ARTEFACTS: 2 quartz pebble hammer-stones; 1 small green silicified ?tuff pebble hammer-stone; 1 rounded 'canon-ball' concretion of calcareous felspathic sandstone, 3" in diameter, apparently used on an upper millstone. Flakes and other fragments numbered 84, 77 were flint, 5 quartz, 1 pink polyzoal foraminiferal limestone and 1 felspathic sandstone.

MOLLUSCS: *Austrosuccinea australis* (Ferussac)—a land snail; *Brachidontes rostratus* (Dunker), *Cellana tramoserica* (Sowerby), *Chiazacmea flammae*

(Q. and G.), *Chloritabadiestes victariae* (Cox), *Hipponyx canicus* (Schmücker), *Lepsiella vinosa* (Lamk), *Patellanax peroni* (Blainville), *Patellaida alticostata* (Angas)—limpet; *Paneraplex castatus* (Blainville), *Subninella undulata* (Solander).

LAYER 4

This horizon consisted of clear yellow sand, with some lenses of hearth material. It was clear that the site was less intensively occupied during this period. The radiocarbon sample, R-728, came from a confined area in the centre of the shelter near the base of this horizon. It consisted of charcoal lumps whose age was estimated at 370 ± 45 years.

BONE ARTEFACTS: 2 flat fragments of cut bone, $1\frac{3}{4}$ " and $3\frac{3}{4}$ " long, subsequently ground to points; 1 pointed bone $5\frac{1}{2}$ " in length, which had been split and then ground at the tip; 1 point, 3" long, broken at the basal end.

STONE ARTEFACTS: Fragments of 4 quartz pebble hammer-stones; 1 deeply patinated white concretionary limestone nodule, $3\frac{1}{2}$ " across and 1" thick, which had been crudely flaked, bifacially, around half its perimeter. Flakes and other fragments numbered 136. 123 were flint, 9 quartz, 2 pinkish polyzoal-foraminiferal limestone, 1 sandy limestone and 1 ferruginized silt-clay.

MOLLUSCS: *Brachidantes rostratus* (Dunker), *Celana tramaseric* (Sowerby), *Chloritabadiestes victariae* (Cox), *Dicathais textilis* (Lamk), *Haliotis ruber* Leach, *Patellanax peroni* (Blainville), *Poneraplex castatus* (Blainville), *Scutus antipades* Montfort, *Subninella undulata* (Solander).

One macropid incisor, some bones of 'parrot-fish', and other indeterminate bone fragments of mammals, birds and fish, were present.

LAYER 5

At the S. end of the trench, this stratum rested on bedrock, and it consisted chiefly of clean yellow decomposed rock. Nearer the centre of the trench, where the rock floor sloped steeply downwards, yellow bands alternated with horizons of black hearth material. The deposit was a firm, smooth sand, very easy to trowel.

ARTEFACTS: No artefacts of bone or stone were recovered. Flakes and other fragments numbered 78. 61 were flint and 17 quartz.

MOLLUSCS: *Brachidantes rostratus* (Dunker), *Celana tramaseric* (Sowerby), *Chloritabadiestes victariae* (Cox), *Dicathais textilis* (Lamk), *Patellanax peroni* (Blainville), *Subninella undulata* (Solander).

LAYER 5A

The division between layers 5 and 5A was arbitrary in the sense that there was no marked stratigraphic break. Alternating bands and lenses of clean yellow sand and ashy material continued down to bedrock at the N. end of the shelter. At the extreme NW. corner of the trench, the rock floor was sloping steeply downhill and the area available for excavation was very confined.

ARTEFACTS: 1 broken quartz pebble hammer-stone, with pronounced abrasion; 2 chunky, pointed primary flakes with faint traces of utilization fracture along the sharpest edge. Flakes and other fragments numbered 22. 12 were flint, and 10 quartz.

A few indeterminate fragments of mammalian bones were present.

Summary of Excavated Finds

Layer No.	Bone Artefacts	Stone Artefacts	Hammer and Anvil-stones	Flakes etc.	C 14 (B.P.)
SHELTER 1:					
1	1	—	7	87	
2	5	1?	13	195	
3	8	—	10	242	
Totals	14	1?	30	524	
SHELTER 2:					
1	4	—	3	107	
2	24	1+5?	10	1017	
3A	7	—	5	181	
3B	7	1 axe	2	129	
3C	6	—	3	84	
4	4	1	4	136	370 ± 45
5	—	—	—	78	
5A	—	—	1	22	
Totals	52	3+5?	28	1754	

Discussion

It is unfortunate that the evidence accumulated was so meagre. However, if these sites can be considered as typical of recent aboriginal camping places, they provide a useful insight into the nature of recent Victorian culture. On a first acquaintance, the evidence suggests that this was merely some prehistoric seafood bar, whose specialized material remains need not be fully representative of the culture of the Otway tribe. Indeed, the fleeting and selective character of habitation on Victorian coastal sites has been stressed by most writers, including Kenyon (1912) and Spencer (1918; 1928: 500), whose opinions on aboriginal stone utilization conditioned subsequent thought in Victoria. Describing the stone flakes found among the middens on Wilson's Promontory, Spencer (1918: 114) commented that they

'are of the crudest possible form. . . . It is only very rarely that any well-made implement is found in the middens, which do not indicate the permanent camps of the natives. They were only . . . temporary eating places—the real camping grounds lying further inland. We only found one ground axe and . . . a bone awl; but such more highly developed implements are of rare occurrence, and must have been accidentally left behind'.

It is interesting to consider Spencer's assumptions in the light of Glen Aire. There is no doubt that the stone material at Aire was of elementary type. 2278 flakes and other fragments were found, yet only about 4 specimens, including one edge-ground axe, could be classified, typologically, as artefacts. For a 'stone age' people, the Otway aborigines were singularly loathe to fashion stone implements. Not a single primary flake or core possessed flake-scars which indicated any particular skill in stone-working. However, despite this apparent agreement between Spencer's opinion and the excavated material, there are many points of difference. While it cannot be denied that the occupation of the Aire sites may have fluctuated seasonally, this is a truism for all aboriginal camping places. Spencer's inference that permanent camps existed away from the coast is doubt-

ful. At least conditions were favourable for the relatively intensive exploitation of the Aire valley, and camps should have been as permanent there as inland. The fact that 5 ft of deposit accumulated during the 270 ± 45 years of pre-European tenancy of Shelter 2, is a pointer to the popularity of the site. It is significant that almost all the molluscan remains were marine species, because as explained above, they were carried to the site from upwards of 2 m. distant, and this suggests a deliberate intention to camp at the site. Consequently, it appears legitimate to classify these shelters as regular aboriginal abodes, and therefore the excavated remains should be a representative cross-section of material culture.

The large number of excavated hammer-stones and struck flakes are proof that stone-working was practised on the site. Therefore, the complete lack of secondary retouch is significant, because surface collections from the vicinity include numerous products of expert stone craftsmen, particularly those areas near the Cape Otway lighthouse, E. of the Aire R. mouth, and between 'Glen Aire' and the Johanna R. Members of this expedition discovered geometric microliths, bond-points and grooved, hammer-dressed, ground axes 3 m. to the W. of the site. It may be postulated, therefore, that the tradition of careful stone implement production had already ceased to condition the material culture and typological preferences of the Otway aborigines, at the time when they first occupied the shelters, perhaps four centuries ago. This means that the untrimmed primary flakes must have been utilized for all the purposes for which the more conventional implements were employed during earlier times. In this eventuality, they were implements and cannot be classified as 'waste flakes'.

Whether the obvious poverty of stone culture at Glen Aire is characteristic of all recent Victorian prehistory is a problem meriting future investigation. If it is, there is an alternative explanation for the occurrence of so few retouched artefacts in coastal middens. It is not, as Spencer believed, because middens were the refuse left by selective and impermanent visitors whose normal abode was further inland. The explanation is that these middens are all so recent that they belong to the latest phase of Victorian prehistory. To a period, that is, when finely made stone artefacts had ceased to be a characteristic of aboriginal culture, whether in coastal or inland areas. It is relevant to note that, at some period, coastal aborigines possessed carefully trimmed artefacts, and such specimens are exposed along the Otway Peninsula. This proves that Spencer was wrong in assuming that 'more highly developed implements' could only be expected in the hinterland. The actual position during the period of European penetration has been obscured by the wide distribution of microlithic artefacts, which, some have assumed erroneously, were in current use amongst the aborigines. It appears to the writer that an objective appraisal of other evidence confirms the general validity of the Glen Aire pattern. Museum collections of ethnographic material have been inspected, together with the best descriptions of material culture, particularly Thomas (1859), Brough Smyth (1878) and Dawson (1881).

It has become evident that, with the exception of edge-ground implements, Victorian aborigines during the last century did not employ stone implements with secondary retouch. Items of material culture which were basic in other parts of the continent, but which were absent in Victoria, included the stone-headed spear, the stone-tipped adze or spear-thrower and the stone knife-blade, with hafted handle or resinous hand-grip. Stone was employed in the 'death spear' to form barbs, but these were simply single or double rows of small, jagged, primary flakes,

which would escape both typological or archaeological identification. Similar stone chips are recorded as cutting or scraping tools (Smyth 1878, i: 304, 381).

Research has convinced the writer that the basic industrial materials of recent Victorian prehistory were of organic origin, most of which could not be expected to survive for archaeological discovery. These materials included wood, bone, animal teeth, reeds, and mussel shell. It is interesting to reflect that, at the time of European settlement, except for the knowledge of edge-grinding, Victorian stone-work was possibly less varied than Tasmanian lithic culture. No explanation can be offered, at this stage, for the abandonment of fine implement production throughout Victoria. It is worth noting that even the quality of axe production deteriorated. The attractive hammer-dressed, edge-ground, grooved axes, which are widely distributed in Victoria, all belong to an earlier period. At least no hafted specimen was collected from the living tribes. Of course, prehistory recognizes no State boundaries, and while these observations apply particularly to Victoria, similar evidence is available across the border in South Australia, where excavation has demonstrated a deterioration in stone craftsmanship during the past 3000 years (Mulvaney 1960: 74).

In the light of this analysis, the surviving bone artefacts at Glen Aire may be considered as standard equipment in aboriginal tool assemblages. Smyth (1878, i: 271, 277, 307, 350) and Dawson (1881: 8) catalogue the types of utilized bones. These included pegs for pinning and stretching animal skins for the drying process, long awls for piercing and sewing the skins, finer needles for line ornamentation on the inside of the cloak and long pins for fastening the finished garment. In addition, they were used as nose-bone ornaments, and the tips and barbs of reed and wooden spears. The Glen Aire artefacts may have been used for all these purposes. Awls were present in the assemblage, and other bones accord with Smyth's description of nose-bone ornaments (1878: 271). Other specimens resemble fish gorges, although Smyth (1878: 202, 391) was only acquainted with wooden gorges in Victoria. Kenyon (1912: 104) believed that most midden bones were used to remove molluscs from their shells.

A bone industry comparable with the excavated material has been reported at many localities around the Victorian coast. In almost every case these finds appear to have been associated with middens exposed in recent dunes. The classic region is in the dune ridges between Port Fairy and Warrnambool, in Western Victoria. The finds from this area have been mentioned at numerous times during the past 50 years, but the most detailed description is that by Mitchell (1958). The National Museum of Victoria has a large collection of artefacts from the area, including a total of 298 utilized bones collected by A. S. Kenyon near Koroit between 1903 and 1918. These specimens, and those illustrated by Mitchell (1958: 195), all have parallels with the Glen Aire material. It is interesting that a Koroit midden deposit has been radiocarbon 14 dated to 538 ± 200 years (C—601; Gill 1955), which is comparable with the 370 ± 45 years estimate for the earliest bone artefacts at Glen Aire.

Smyth (1878, i: 240) provides a detailed description of the finds made in a dune midden to the E. of Cape Otway lighthouse. They included an edge-ground axe and a variety of bone tools, whose description accords with the Glen Aire finds, 10 m. away. Similar bone tools have been reported further east along the Victorian coast, in recent midden deposits at Cape Patterson (*ibid.*: 241) and Wilson's Promontory (Spencer 1918). However, bone artefacts are not confined

to the coastal fringe. They are recorded from inland sites at Camperdown (Smyth 1878, i: 365), Leigh River (Mitchell 1958: 199) and Glenthompson (information, Mr K. Sutton).

It is evident that the Glen Aire discoveries were negative and of little intrinsic merit. However, they highlighted features which may prove to be relevant to any assessment of Victorian prehistory. It is hoped that further excavations within the immediate future will test the validity of suggestions advanced here. It is, indeed, unfortunate that the aborigines of recent Victorian prehistory did so little to endear themselves to the archaeologist.

Acknowledgements

My debt to the discoverers of the site, Messrs Donald Currie and Kingsley Sutton, is obvious. It is to be hoped that their example of scientific field work is followed by all collectors of stone implements. Mr Sutton assisted on the excavation, and his discussions on aboriginal culture have proved stimulating. Mrs Winifred Denney, of 'Glen Aire', facilitated the excavation in many ways.

The expedition was a joint University and Museum project, and I wish to thank Mr C. W. Brazenor, Director of the National Museum of Victoria, for his support. Mr A. Massola, Museum Anthropologist, was a member of the field team. Most of the labour for the dig was provided by History students of the University of Melbourne. All the finds have been deposited in the National Museum.

Technical assistance was supplied by the undermentioned. Mr D. A. Casey acted as surveyor and photographer. Miss J. Hope MacPherson, National Museum of Victoria, identified the molluscan remains. The following staff members of the University of Melbourne gave specialized assistance: Associate Professor L. J. Ray, Department of Anatomy, examined the human skeletal remains; Mr J. A. Thomson, Department of Zoology, studied the scanty faunal evidence; Mr J. Bowler, Department of Geology, identified some of the stone material. Through the co-operation of Dr T. A. Rafter, Director, Division of Nuclear Sciences, D.S.I.R., New Zealand, the radiocarbon 14 age determination was obtained within 6 months of submission of the sample.

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Explanation of Plates

PLATE I

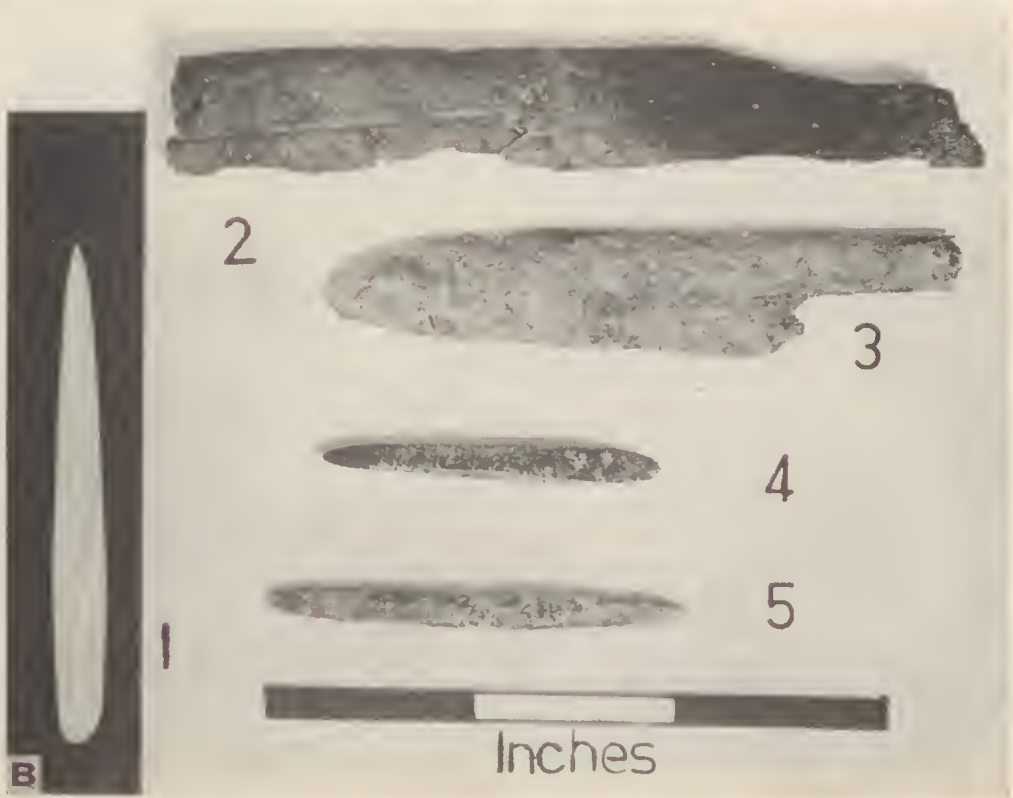
- A—The deposit in Shelter 1, looking W., at a late stage of the excavation.
 B—Bone artefacts excavated in Shelters 1 and 2.

PLATE II

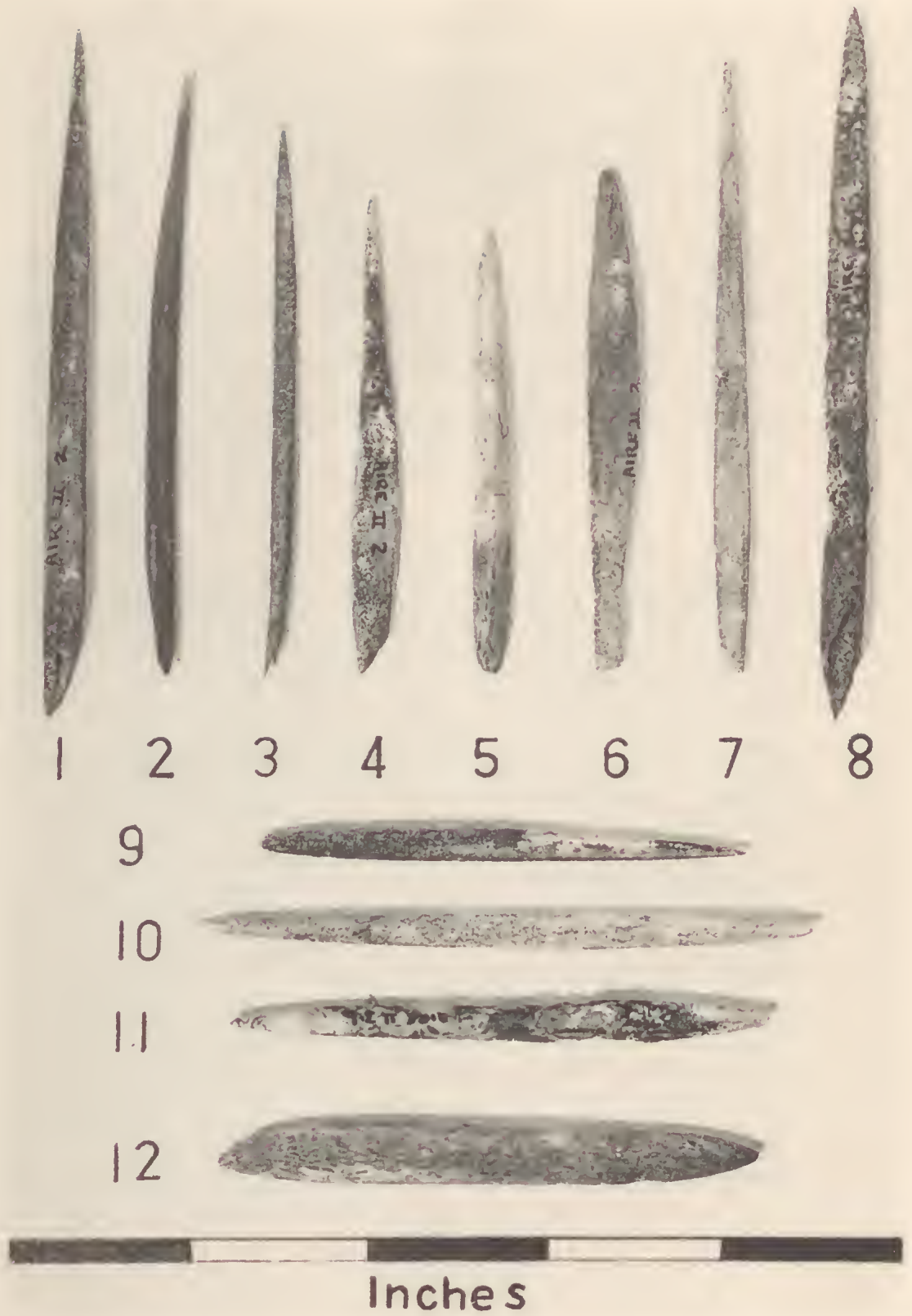
- A—General view of Shelter 2 looking SE.
 B—The human remains lying on the surface of layer 2, Shelter 2.

PLATE III

- Bone artefacts from Shelter 2.







THE DUNE SUCCESSION AT CORNER INLET, VICTORIA

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[Read 13 July 1961]

Summary

1 This paper outlines the physiography of two of the islands in Corner Inlet, Victoria—Sunday I. and Clonmel.

2 Four land types are distinguished—dune ridges, sandy terraces, salt swamp and fresh-water swamp.

3 The zonation of the vegetation and soils on the dune ridges of Clonmel and Sunday I. is described; the evidence is presented for regarding the five major zones as stages in primary plant succession on new terrain.

4 Extensive wooded terraces on sandy soils are not considered as stages in the primary dune succession; the origin of the terraces is ascribed to the emergence of unvegetated sand flats formed on the northern coasts of the dune ridges.

5 The vegetation and soil of small areas of damp heath woodland are also described and the origin of this community is discussed.

Physiography

Much of the coast of E. Victoria is bordered by systems of parallel dune ridges at the back of sandy beaches. It is generally believed that such dunes are formed successively on a shoreline advancing seaward by sand accumulation. Sand derived from the sea floor, from eroded coasts or from material carried into the sea by wind or rivers is delivered to the shoreline by wave action, and built into parallel foredunes by the combined effects of wind and dune vegetation. Davies (1957) has emphasized the difference between the constructive action of flat ocean swell, which moves sand up on to the beach, and the destructive action of steep storm waves, which withdraw sand from the beach and carry it offshore. This alternation of constructive and destructive wave action has been termed 'cut and fill' by American geomorphologists. When 'fill' exceeds 'cut', sand is built into a bank or berm (Pl. IV, fig. 1, 2) along the length of the beach, but this is often cut away by storm waves. Eventually, as more sand is deposited on the shoreline, a berm may survive as a permanent feature colonized by dune grasses, which tend to trap sand blown up the beach by onshore winds. In this way, a foredune is built along the back of the beach, and will continue to grow until a newer foredune cuts off the supply of wind-blown sand. Dune grasses are then succeeded by shrubs and trees, and the parallel dune ridges are stabilized. At any stage vegetated dunes may be eroded by wave action or by wind (blow-outs). In Victoria there is evidence that over the last 40 or 50 years many dune systems have been cut back by storm waves, and good examples of embryonic dunes are infrequent in the Port Phillip and Western Port areas.

The dune succession has been studied on Clonmel and Sunday I., two of the group of barrier islands at the mouth of Corner Inlet, a large shallow marine embayment NE. of Wilson's Promontory (Fig. 1). Sunday I. is 5 m. in length

from E. to W. and 2 m. in breadth. It is separated from the mainland near Port Albert by a strait 3 m. broad at high tide.

The island has a central tract of sand ridges running from E. to W., almost encircled by swamps and salt marshes; on the SE. corner there is a smaller sand-ridge tract known as the Drum, and further to the SE. lies Clonmel, an island at the SW. termination of the Ninety Mile Beach (Fig. 1). The sand ridges rise to

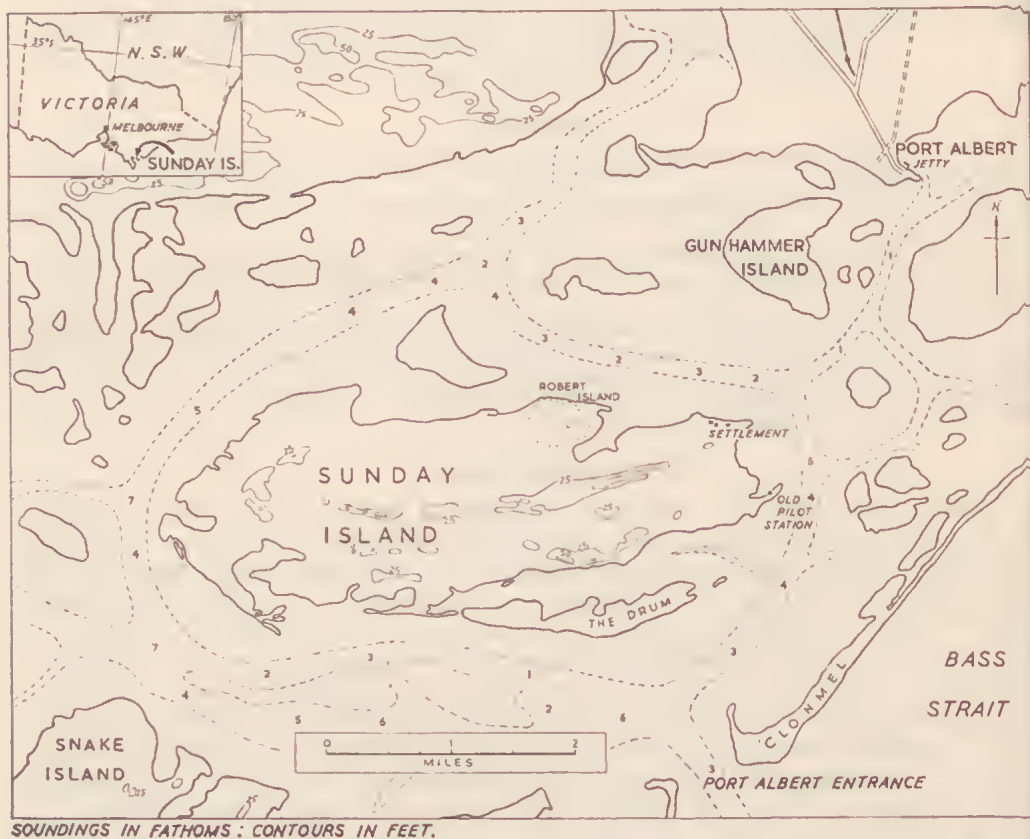


Fig. 1—Map of part of Corner Inlet, Victoria, showing Sunday I., the Drum and Clonmel; based on military maps and Admiralty charts.

between 20 and 60 ft above sea level, and form a complex pattern indicating several stages of foredune formation interrupted by erosion of the shoreline. These foredunes were undoubtedly formed by the processes previously described, and their complex pattern indicates changes in the pattern of waves entering Corner Inlet that were probably due to changes in coastal and offshore configuration in Recent times.

A thorough study of the geomorphology of Corner Inlet has not yet been made, but the present field survey, coupled with the inspection of aerial photographs, has led to the following conclusions.

Sunday I. is a compound barrier island developed off the estuaries of the

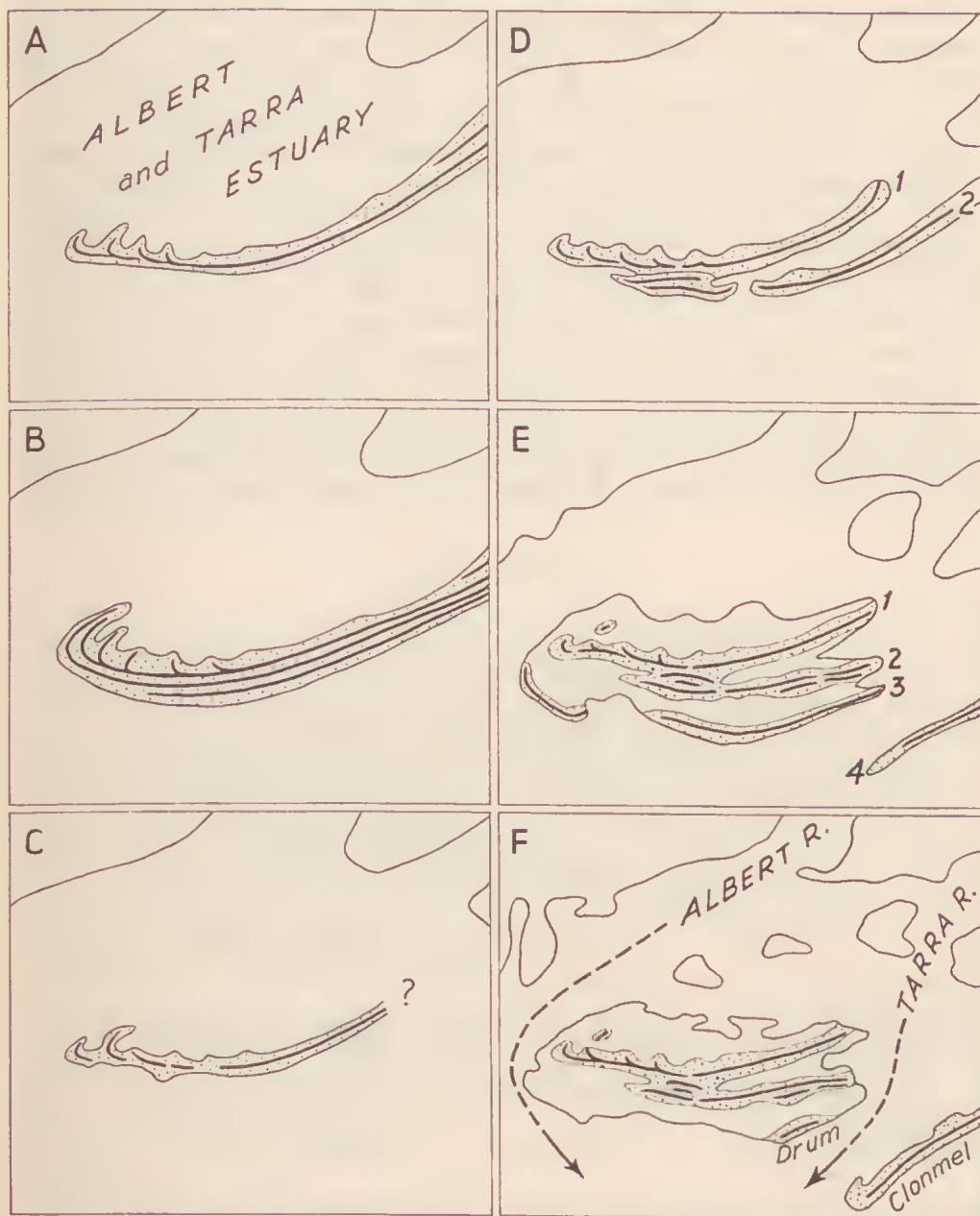


Fig. 2—The evolution of Sunday I., in terms of the successive growth of the coastal barrier at the SW. end of the Ninety Mile Beach and its successive dissection by tidal channels at the mouths of the Albert and Tarra estuaries.

A early stage recurved spit
 B widened coastal barrier
 C erosion and dissection

D second stage recurved spit
 E emergence and third stage spit
 F present pattern

Albert and Tarra R., and the main sequence of development is indicated diagrammatically in Fig. 2. It is probable that the evolution of this island post-dates the general submergence of the coast by the world-wide Postglacial marine transgression, and tectonic subsidence of the land has almost certainly occurred around Corner Inlet. The Albert and Tarra valleys were partly drowned by the submergence to form estuaries and a recurved spit developed soon afterwards, partly separating them from the sea (Fig. 2A). This was widened and lengthened, and parallel foredunes developed on it (Fig. 2B), but then wave conditions changed, perhaps as the result of submergence or subsidence, and the spit was eroded and dissected (Fig. 2C). A newer spit was then formed in front of it, and an eroded embayment was filled with newer foredunes (Fig. 2D). At this stage, the adjacent waters must have been shallow, with sandflats exposed at low tide. Later, an emergence, due either to an uplift of the land or a drop in sea level, exposed the adjacent sandflats to form sandy terraces, and led to the formation of newer spits on the seaward side (Fig. 2E). The outline of the barrier island has since been modified by wave action, by the scouring effects of tidal currents in the estuaries, and by the evolution of bordering salt marshes and mangrove swamps. The range of spring tides at Port Albert is 8 ft. Strong tidal currents develop in the estuaries,

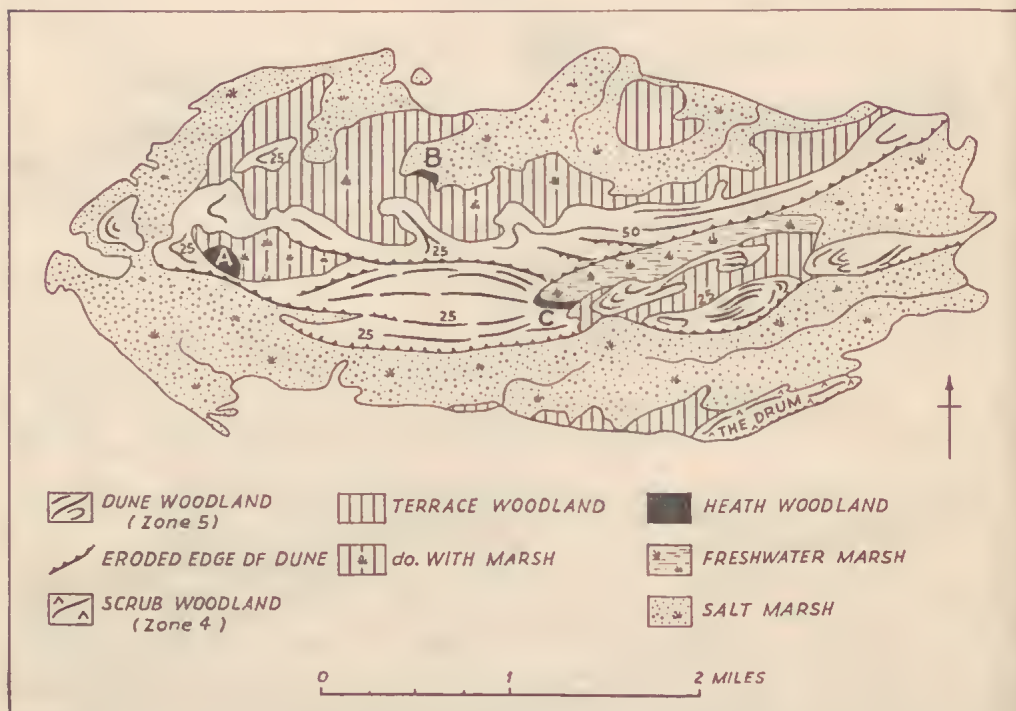


Fig. 3—The major land types on Sunday I., based on ground surveys and aerial photographs.

- (1) dune ridges, shown as dune woodland and scrub woodland
- (2) sandy terraces, shown as terrace woodland with or without marsh
- (3) salt marshes and (4) freshwater marshes
- (5) heath woodland, whose origin is discussed in the text.

and at low tide extensive sandflats and mudflats are laid bare on the borders of the island and on the landward side of Clonmel. There has been further growth of the outer spit at Clonmel.

Sunday I. and Clonmel comprise four well-defined land types (Fig. 3). The oldest dune ridges are in the centre of Sunday I.; the 'Drum' is part of a younger ridge and Clonmel bears dune ridges in the course of formation. On Sunday I., eroded dune cliffs occur on the NE. and SE. shores and steep slopes, marking the position of eroded dune cliffs formed earlier (when 'cut' exceeded 'fill'), are traceable in the dune ridge country. The sandy terraces on the landward side of each set of dune ridges are presumed to be old sandflats, exposed by emergence or by a fall in sea level. Salt marshes have formed in the sheltered marginal areas between the dune ridges and on the inland coasts of Sunday I. Other low-lying areas enclosed by or adjacent to sand ridges inland have developed as extensive freshwater marshes as a result of the seepage of rain water from the dunes.

The islands of Cornet Inlet are geologically of Recent formation. In this paper we describe 5 distinct zones of vegetation on the dune ridges and give the evidence for the view that these represent 5 stages of primary plant succession on new terrain. We also deal briefly with 2 other communities on sandy soils, terrace woodland and heath woodland, and discuss their origin.

Recent History

The open country of the mainland, behind Port Albert, was settled and stocked by 1844, and Sunday I. has been used for grazing since at least 1860. A small pilot station was inhabited from 1900-1922, and a homestead was occupied from 1918-1938. At first the grazing was by cattle, some 350 head, but later the island became a sheep run, carrying as many as 2,200 animals at any one time. A small area of the N. terrace was planted to *Acacia* (for tan dark) circa 1938, and from that time to 1950 the island was grazed mainly by wallabies and by rabbits which have been abundant for 50 years. Goats were introduced in 1928, and a few still ran wild on the S. marshes in 1947. Wallabies and goats were exterminated by dogs in 1950, when the rabbit population was also greatly reduced by the spread of myxomatosis from the mainland. In 1950 more intensive sheep farming was initiated. The application of superphosphate and the introduction of pasture species will cause considerable local changes in the vegetation.

Most of the grazing was undoubtedly in the freshwater swamps, on the damper parts of the terrace woodland and on the salt marshes. The plant communities of the sand ridges and hollows still appear to be in a natural state. They carry some 126 of the total 254 vascular plants recorded for the island. Of this total, 32 are aliens, but the majority of these are found mainly on terrace woodland near the settlement. Only 6 alien species were recorded for dune woodland (Table 2), and the 8 aliens in the younger stages of the dune sere are clearly of no ecological significance.

Occasional fires have been reported over the period 1908-1949. They have caused no serious damage to the standing trees, but may have modified the nature of the ground flora—in particular by encouraging the growth of bracken in dune and terrace woodland. There is no field evidence to suggest that fire has been an important factor in modifying succession.

The present vegetation has been developed in a mild, maritime climate (in Thornthwaite's (1948) Symbols, B₁, B¹/B¹₂, S, a¹).

TABLE 1

Species of the dune sere and heath woodland, alien species omitted

Stage of sere—Zone	1	2	3	4	5	—
Species	Embryonic dune Clonmel	Fore dune Clonmel	Dune scrub Clonmel	Old dune scrub The Drum	Dune woodland Sunday I.	Heath woodland Sunday I.
<i>Festuca littoralis</i>	Dom.	+				
<i>Atriplex cinerea</i>	+	+	+			
<i>Senecio lautus</i>	+	+				
<i>Cakile maritima</i>	+	+				
<i>Apium prostratum</i>		+				
<i>Carpobrotus rossii</i>		+	+			
<i>Crassula macrantha</i>		+				
<i>Diphyssa australe</i>		+	+			
<i>Frankenia pauciflora</i>		+				
<i>Plagianthus spicatus</i>		+				
<i>Salicornia australis</i>		+				
<i>Spinifex hirsutus</i>		Dom.	+			
<i>Suaeda maritima</i>		+				
<i>Tetragonia implexicoma</i>		+				
<i>Helichrysium gunnii</i>		+	Co-Dom.			
<i>Olearia axillaris</i>		+	Co-Dom.			
<i>Acacia longifolia</i> var. <i>sophorae</i>			Co-Dom.	+		
<i>Agrostis avenacea</i>			+			
<i>Dianella revoluta</i>			+		+	
<i>Muehlenbeckia adpressa</i>			+	+	+	
<i>Poa australis</i>			+			
<i>Polycarpon tetraphyllum</i>			+		+	
<i>Senecio glomeratus</i>				+		
<i>Stackhousia spathulata</i>			+			
<i>Leptospermum laevigatum</i>			++	Co-Dom.		
<i>Leucopogon parviflorus</i>			++	Co-Dom.	+	
<i>Acaena ovina</i>			+	+	+	
<i>Banksia integrifolia</i>			+	Co-Dom.	+	
<i>Clematis microphylla</i>			+	+	+	
<i>Gnaphalium involueratum</i>			+	+	+	
<i>Myoporum insulare</i>			+	+	+	
<i>Rhagodia baccata</i>			++	+		
<i>Scirpus nodosus</i>			+	+	+	
<i>Acianthus exsertus</i>				+	+	
<i>A. caudatus</i>				+	+	
<i>Amperea xiphoclada</i>				+	+	+
<i>Billardiera scandens</i>				+	+	
<i>Burchardia umbellata</i>				+	+	
<i>Bursaria spinosa</i>				+	+	
<i>Caladenia carnea</i>				+	+	
<i>C. latifolia</i>				+	+	
<i>Cassinia aculeata</i>				+	+	
<i>Casuarina stricta</i>				+	+	
<i>Centaurium minus</i>				+	+	+
<i>Clematis aristata</i>				+	+	
<i>Comesperma volubile</i>				+	+	
<i>Dichopogon strictus</i>				+	+	
<i>Drosera auriculata</i>				+	+	+

+ Present

++ Abundant

(+) Rare

Stage of sore—Zone	1	2	3	4	5	—
Species	Embryonic dune Clonmel	Fore dune Clonmel	Dune scrub Clonmel	Old Dune scrub The Drum	Dune woodland Sunday I.	Heath woodland Sunday I.
<i>Drosera planchonii</i>				+	+	+
<i>Eucalyptus viminalis</i>				+	+	Co-Dom.
<i>Gahnia radula</i>				+	+	
<i>Galium propinquum</i>				+	+	
<i>Geranium pilosum</i>				+	+	
<i>Glycine clandestina</i>				+	+	
<i>Goodenia ovata</i>				+	+	
<i>Kennedyia prostrata</i>				+	+	+
<i>Lepidosperma concavum</i>				+	++	+
<i>L. elatius</i>				+		
<i>Lindsaya linearis</i>				+	+	
<i>Luzula campestris</i>				+	+	
<i>Pterostylis pedunculata</i>				+	+	
<i>Schizaea bifida</i>				+	+	+
<i>Spyridium parvifolium</i>				+	+	
<i>Stylidium graminifolium</i>				+	+	
<i>Themeda australis</i>				+	+	
57 species listed in Table 2					+(57)	
<i>Acacia verticillata</i>					+	++
<i>Acrotriche serrulata</i>					+	++
<i>Astroloma humifusum</i>					+	++
<i>Banksia serrata</i>					Co-Dom.	Co-Dom.
<i>Calorophus lateriflora</i>					+	+
<i>Danthonia semiannularis</i>					+	+
<i>Epacris impressa</i>					+	+
<i>Euphrasia collina</i>					+	+
<i>Halorrhagis teucrioides</i>					+	+
<i>Hibbertia acicularis</i>					+	+
<i>Imperata cylindrica</i>					+	+
<i>Lagenophora stipitata</i>					+	+
<i>Leptospermum juniperinum</i>					+	+
<i>Leucopogon virgatus</i>					+	+
<i>Lomandra longifolia</i>					+	+
<i>Monotoca scoparia</i>					+	+
<i>Pteridium esculentum</i>					++	(+)
<i>Wahlenbergia gracilis</i> agg.					+	+
<i>Xanthorrhoea australis</i>					+	+
<i>X. minor</i>					+	+
<i>Casuarina pusilla</i>						+
<i>Banksia marginata</i>						+
Total No. of species	4	16	22	43	118	30
Zone	1	2	3	4	5	—
Stage of sore	1	2	3	4	5	?6

Total species of dune sore: 141

+ Present

++ Abundant

(+) Rare

Rainfall is not likely to differ appreciably from that of Port Albert, where 70 years of observations give an annual precipitation of 26 in., fairly evenly distributed over the year, but with maxima in spring and autumn and minima in the summer and winter. The rainfall is reliable and the number of days with measurable rain is about 140 per year. The annual maximum of temperature on the island is likely to reach 100°F., the annual minimum 38°F., with 10 days of maximum temperature over 90°F. and only four days with a minimum below 40°.

The Dune Succession

We describe 5 well-defined zones of vegetation on dune ridges, at the same time marshalling the evidence which clearly indicates that these are 5 stages in plant succession (Table 1).

ZONE 1. EMBRYONIC DUNE—CLONMEL I.

On the seaward coast of Clonmel long sand ridges lie parallel to the ocean swell. That nearest the sea is the unvegetated 'beach ridge' or 'berm', just above high tide level and with its steeper face inland (Pl. IV, fig. 1, 2). This is clearly formed by sand delivered to the beach by wave action. On its surface occur a few very small embryonic dunes, of wind-blown sand accumulated round the base of plants. Other and larger embryonic dunes occur along the seaward face of the next parallel dune ridge, the fore dune, which is presumed to be built on an earlier berm.

The dominant plant of the Clonmel embryonic dunes, and the chief sand binder, is *Festuca littoralis* (Pl. IV, fig. 1, 2), which takes the place here of *Agropyron junceum* and *Ammophila arenaria* of the English dunes. *Atriplex cinerea* (a shrub up to 4 ft high) and the annual *Senecio lantus* occur occasionally, but play no important part in sand binding. *Cakile maritima* and the introduced *Sonchus asper* are the only other species recorded for this zone, *Cakile*, as in Europe, being really a plant of the drift-line along the foreshore.

The light yellow beach sand in this region is mainly quartz with about 5% CaCO₃ and a pH of 7.8. The sand of the embryonic dunes has the same appearance, still contains CaCO₃ (2.3%) but is neutral in reaction. There is, however, no true soil formation and the vegetation is largely open and patchy.

ZONE 2. FORE DUNE—CLONMEL I. (Pl. IV, fig. 2-4)

The fore dune on Clonmel is a long ridge of sand, up to 25 ft high, parallel to the present beach ridge and clearly formed on an earlier ridge by the coalescence of embryonic dunes, after further accretion of blown sand. The vegetation includes the 4 species of Zone 1 but is less open. Another 13 native species of flowering plant occur. The dominant plant is *Spinifex hirsutus*, a sand-binding grass with a long, creeping rhizome and an efficient method of seed dispersal, the spiny, globular fruiting heads being blown along the sand by the wind until they catch in some obstruction, or break up. The advance of the rhizomes of this grass into embryonic dunes is shown in Pl. IV, fig. 2, 3, 6. The two large shrubs, *Olearia* and *Helichrysum* (Table 1) are clearly invading from Zone 3. 6 of the 8 other species also occur in the neighbouring salt marshes, and although they may help in stabilizing the surface, they are not true dune builders. The following alien weeds were present:—*Rumex pulcher*, *Silene anglica*, *Anagallis arvensis*, *Picris hieracioides*.

On the seaward side of the fore dune the sand between the plants is bare, and its surface layers are still pale yellow and unstabilized; even near the plants themselves there is no free litter or obvious darkening of the surface soil. Near the boundary of Zones 2 and 3, however, the dunes are, in places, becoming stabilized

and the surface may be thickly carpeted with mosses and lichens, of which the major species are *Tortula princeps*, *Bryum billardieri* and *Cladonia* spp.

ZONE 3. DUNE SCRUB ON STABLE DUNE RIDGES—CLONMEL I.

Parallel to and close to the fore dune and forming the main part of Clonmel I. is a series of roughly parallel dune ridges little higher than the fore dunes, but carrying a closed community of shrubs which cover ridge and hollow (Pl. IV, fig. 4). The ecotone between Zones 2 and 3 is very narrow.

The shrub species which share dominance are *Acacia longifolia* var. *sophorae*, *Olearia axillaris* and *Helichrysum gunnii*. Of these, the last two are occasional in the fore dune. The *Acacia* grows as a fairly erect shrub in the main community, where it resembles a more fleshy and smaller form of the inland *A. longifolia*. On the seaward margin of the scrub it adopts a more creeping habit, with long, decumbent branches sometimes rooting at the nodes and slowly invading the fore dunes. Accompanying these 3 shrubs, but rather less frequent, are *Leptospermum laevigatum*, *Leucopogon parviflorus*, *Rhagodia baccata* and, still less frequent, *Myoporum insulare*. These shrubs grow very closely together, reaching an average height of 20-25 ft, and entrance into the scrub is difficult. They cast a dense shade in the swales of the dune where the ground flora is very sparse, but the canopy is more open on the ridges where *Acaena ovina* often covers the ground. In other more open places mosses (*Tortula princeps*, *Tortella calycina*, *Bryum billardieri*, *Ceratodon purpureus*, *Funaria hygrometrica*) are abundant. Evidence of succession is provided by the persistence of *Spinifex* and *Atriplex* in the community, and also by the presence of dead *Spinifex* shoots. Moreover, the soil is slightly more mature than that of stages 1 and 2, especially in the swales. There is a thin litter of dry leaves and the surface 6" now has a greyish colour due to the admixture of humus. This layer has a pH of 6.8 and the sand immediately beneath contains 3% CaCO_3 ; there is no true soil profile or podsolization.

The remaining species, all but one of them occasional herbs of little importance, are listed in Table 1. The rare occurrence of one tree, *Banksia integrifolia*, is regarded as an indication of the seral nature of this stage and the possibility of its eventual replacement by scrub woodland of the type found on the Drum, designated as stage 4 of the zonation.

The dune scrub, where it occurs on Clonmel, persists almost to the water's edge on the N. coast of the island. There is, however, a strip of vegetation along a drift-line rich in *Atriplex cinerea* and, with other species of Zone 1, separating the scrub from the open sand. There is clearly no terrace formation on the inner side of this island, but there is an extensive, unvegetated sandflat exposed at low tide, separated from Sunday I. by a deep estuarine channel. This area will be referred to again in the discussion of terrace woodland.

ZONE 4. SCRUB WOODLAND—THE DRUM DUNE RIDGE

The Drum is the local name of a long, narrow, sandy ridge running parallel to Sunday I. itself and separated from it by wide mudflats with fringing salt marshes, which are inundated at high tide. Here we deal only with the dune ridge, 20-30 ft high and about 50-100 yds wide, on the seaward side of the Drum. N. of this is a narrow flat terrace carrying *Eucalyptus viminalis* and bracken or *Melaleuca* scrub, obviously closely related to the terrace woodland of the main island.

On the S. side of the Drum ridge the dune is considerably eroded and forms

a cliff, 6-15 ft high. No traces remain of any early stages in primary succession on the Drum itself; there are only a few secondary embryonic dunes on the shore below the cliff. The evidence that the Drum dune ridge represents Zone 4 in the succession is provided partly by its position and height, partly by its soil characteristics and mainly by the major woody species of the dune scrub (Table 1). These species also occur in Zones 3 and 5, but more sparingly in both. They are the coastal banksia (*B. integrifolia*), up to 40 ft. high, and 2 smaller species, up to 15-20 ft high, *Leptospermum laevigatum* (the more abundant) and *Leucopogon parviflorus*. *Acacia longifolia* var. *sophorae* (of Zone 3) is rare, *Helichrysum gunnii* (Zone 3) and *Banksia serrata* (Zone 5) are absent. There are a few scattered trees of *Eucalyptus viminalis*, the other co-dominant of Zone 5.

The ground flora of the whole of the Drum ridge is variable, and it is doubtful whether all the species recorded represent those naturally associated with the woody plants already named.

These shrubs and trees arise from an A horizon which is now buried under 2-3 ft of blown sand and it appears therefore that, during the lifetime of the woody species, secondary dune formation has occurred. The nature of this new soil surface and of the plants it bears, therefore, has little relevance to the problem of primary succession. The species listed in Table 1 are those which occur on those parts of the Drum ridge least affected by blown sand, and it will be noted that they include species from both Zones 3 and 5 (Dune woodland). Other species on the Drum dune, some of them aliens (°) are:—*Carpobrotus rossii*, *Acaena ovina*, °*Sonchus asper* and °*S. oleraceus*, *Gnaphalium luteo-album*, °*Hypochaeris radicata*, *Senecio glomeratus*, °*Fumaria officinalis*.

For reasons given above, the soil of the Drum ridge was not fully investigated. It is clear, however, from a study of the original but mostly buried A horizon of Zone 3, that it is a dark layer fairly rich in humus; the soil is rather more mature than that of Zone 3, but shows very little evidence of the podsolization of Zone 5. The sand covering the earlier profile is still calcareous (1.8-3% CaCO_3) and alkaline (pH 7.3-7.5). The bryophyte flora is similar to that of Zone 5.

ZONE 5. THE DUNE WOODLAND

About one-third of the area of Sunday I. is made up of old stable sand dunes, reaching 50 ft above sea level (but often less) and covered by an open mixed woodland of *Eucalyptus viminalis* and *Banksia serrata*. The dunes run approximately E. to W. in ridges, with the steeper sides facing the sea, the ground between the ridges being undulating. The woodland occupies almost the whole of this undulating and ridged area (Fig. 3). The vegetational community is closely similar to that found in the neighbouring coastal regions of the mainland, on similar soils.

E. viminalis, growing to 30-40 ft, often shares dominance with *B. serrata* (30 ft). In some parts of the island these 2 species are present in more or less equal numbers, but there are large areas of dune woodland in which *Banksia* is the more abundant tree. Such variations are not correlated with topography, but may be connected with unequal resistance or exposure to fire, coupled with heavy seedling of one species or one specimen. This is borne out by the fact that, although seedlings of both trees are frequent, they are of local occurrence. There are, for instance, areas of some acres dominated by *Banksia* but very rich in *Eucalyptus* seedlings. Other areas with mixed mature trees are rich in *Banksia* seedlings and

lacking in young *Eucalyptus*. Apparently there has never been a really severe fire on the island, but it has twice been burnt in part within living memory.

Although from the sea the trees form an apparently solid front of vegetation, the woodland is actually very open (Pl. V, fig. 1). The crowns very rarely meet, and the shade cast by leaves is very light except directly under the dense *Banksia* crowns. The *E. viminalis* is of the typical coastal form, with straggling growth and trunks up to 2 ft diameter, with rough, grey bark to the tops of the main branches. Both the co-dominant tree species flower and fruit freely and show little sign of extensive fire damage.

The distribution of *Banksia integrifolia* on these islands is of considerable interest. It occurs sporadically in Zone 3 on Clonmel, but it is a characteristic species of the Drum dune. Here it occurs with *Leptospermum laevigatum* and *Leucopogon parviflorus* on stable but very immature soils, as it does in the more westerly parts of the Victorian coast, e.g. at Port Phillip. It is also found in dune woodland on Sunday I., where, however, it has a very restricted and significant distribution. It occurs in a very narrow strip of the eroded S. coast dune and there are also a few trees on the seaward eroded edge of the main island dune ridge which faces the central marsh (Fig. 3). Elsewhere on Sunday I. it is completely absent, its place being taken in climax dune woodland by *B. serrata*. It therefore seems probable that the existing trees of *B. integrifolia* on Sunday I. persist as the remnants of an earlier seral stage, resembling that of the Drum ridge. The detailed nature of the soil under these relies has not been investigated, but it is clear that the relationship of *Banksia* species to soil pH is of considerable interest.

Apart from a few exotics on the old pilot station area, the only other trees on the island are *E. obliqua* (one mature specimen only, with a nearby seedling) and a small grove of *Acacia melanoxylon* (blackwood). Both of these species are regarded as chance introductions from the mainland. The scattered taller shrubs are too few to form a definite shrub layer, except locally where *Acacia suaveolens* forms thickets up to 5 ft high.

The dominant plant of the field layer is *Pteridium esculentum* (Pl. V, fig. 1), although the smaller and less obvious sedge, *Lepidosperma concavum*, is equally frequent and may be regarded as the subdominant. The bracken only rarely forms dense societies, but is fairly evenly distributed over ridge and hollow, with fronds averaging 2-3 ft in height and so spaced as to allow plenty of light to reach the ground. This is very sparsely vegetated in summer with flowering plants. On the NE. side of the island, subject to strong easterly winds, the soil surface is often bare, and in some parts it is still being slowly raised by the deposition of white blown sand.

The field layer contains many other species of shrubs and herbs, but few of them are frequent except locally. Table 2 gives a list of those species encountered on our 3 visits. The general aspect of the community is determined by the bracken, and other species provide only a fraction of the sparse cover. Even in spring, when the orchids and grasses, especially *Aira caryophyllea*, are in leaf and flower, the vegetation is open except in the sheltered aspects of the old dune ridges; here bryophytes and lichens often form a dense carpet. The many local variations in frequency and density of the other species may possibly be related to shelter and dispersal, but one particular tendency may be noted; those species characteristic of heath or heath woodland (marked *) increase in frequency towards the W. end of the island, where small patches of true heath woodland exist.

TABLE 2
Species of the dune woodland (Zone 5)

TREES:

Eucalyptus viminalis, co-dominant
Banksia serrata, co-dominant
B. integrifolia, rare and local

SHRUBS, DWARF WOODY PLANTS, CLIMBERS, PARASITES:

(a) Frequent to occasional—

*Acacia longifolia**A. stricta** *Acrotriche serrulata** *Astroloma humifusum** *Epacris impressa**Goodenia ovata**Helichrysum gunnii**Leucopogon ericoides**Leucopogon parviflorus**Monotoca elliptica**M. scoparia**Muehlenbeckia adpressa*

(b) Uncommon to rare—

*Acacia ulicifolia**Cassinia aculeata** *Leptospermum juniperium*(c) *A. Melanoxydon**Bursaria spinosa** *L. myrsinoides*(c) *A. mearnsii**Cassyttha glabella** *Leucopogon virgatus**A. verticillata**Casuarina stricta**Myoporum insulare**A. verticillata**Clematis aristata**Phrygilanthus*var. *latifolia**C. microphylla*

cucalyptifolius

*A. verticillata**Correa reflexa**Pimelia linifolia*var. *ovoidea** *Dillwynia floribunda**Platylobium triangularis**Amperea xiphoclada**Exocarpus strictus**Pomaderris aspera** *Aotus villosa** *Hibbertia acicularis**Pultenaea daphnoides**Billardiera scandens** *H. fasciculata**P. gunnii** *Bossiaea cinerea** *H. prostrata**Rhagodia baccata** *Bursaria spinosa** *H. stricta**Spyridium parvifolium** *B. prostrata**Hakea scirica*

FIELD LAYER:

(a) Abundant—

Pteridium esculentum, dominant*Lepidosperma concavum*, sub-dominant

(b) Frequent to occasional—

*Acaena ovina**Euphrasia collina**Poa australis**Acianthus exsertus* φ*Gahnia radula*o *Polycarpon tetraphyllum**A. caudatus* φ*G. filum**Pterostylis alata* φ*A. reniformis* φ*Galium propinquum**P. concinna* φo *Aira caryophyllae* φ*Geranium pilosum**P. curta* φ*Burchardia umbellata* φ*Gnaphalium**P. nutans* φ*Caladenia carnica* φ

involucratum

P. pedunculata φ*C. latifolia* φ*Hypoxis glabella* φ*P. vittata* φ* *Calorophus lateriflora**Halorrhagis leucoides**Schizaea bifida**Centrolepis strigosa*o *Hypochaeris radicata**Scirpus nodosus*o *Centaurea minus** *Hypolaena fastigiata**Spergularia rubra*o *Cerastium glomeratum**Helichrysum scorpioides**Stackhousia spathulata**Comesperma volubile**H. semipapposum**Stylidium**Crassula sieberiana**H. gunnii*

graminifolium

*Danthonia semiannularis**Imperata cylindrica**Themeda australis**Dianella revoluta**Kemedia prostrata**Thysanotus patersonii**Dichondra repens**Lagenophora stipitata**Viola hederacea**Dichopogon strictus**Lepidosperma gladiatum**Wahlenbergia gracilis**Dipodium punctatum**Lomandra filiformis*

agg.

* *Drosera auriculata**L. longifolia** *Xanthorrhoea australis** *D. planchonii* var.*Luzula campestris** *X. minor*

albiflora

*Marianthus procumbens** *Xanthosia pusilla**Senecio quadridentatus*o *Oxalis corniculata*

BRYOPHYTES:

*Lophocolea heterophylloides**Funaria hygrometrica**Tortella calycina**Brachythecium**Bryum affine**Scmatophyllum*

salcbrosum

B. pachytheca

homomallum

*Campylopus introflexus**Hypnum cupressiforme**Tortula princeps**Ceratodon purpureus*

LICHENS:

*Cladonia aggregata**Ramalina calicaris**C. Pyxidata**Usnea barbata*

*Species generally more frequent on the W. dune ridges and indicative of the trend to heath woodland; φ vernal; o alien; (c) casual.

The soil of the dune woodland is a very light quartz sand showing clear but not advanced podsolization (Pl. V, fig. 2). There is some little humus in the top foot or two but no well-defined Ao litter horizon. The surface layers have a pH of 4.5 and the pH range in the profile is from 4.5 to 8.0.

The A horizon varies in depth from 30 in. to 45 in.; it is a light grey sand above, grading to almost pure white below. The B horizon varies from a wide, ill-defined layer of red-ochraceous sand as much as 4 ft thick to a compact, dark brownish-red layer only a few inches thick, but it is never a hard, rocky pan. The horizon is often ill-defined below, extending downwards in long, vertical streaks, where the red colour is often most intense. The C horizon is a pale yellow siliceous sand. No bedrock or calcareous concretions have been found even in pits dug below the water table. Some old stumps with calcareous concretions on their surface are found along the shore line near the settlement, but these have clearly fallen from the eroded edge of the dune and calcification appears to be very recent.

Most of the roots and rhizomes occupy the A2 horizon, but *Pteridium* rhizomes may be found at 2 ft and the roots of *Banksia* and *Eucalyptus* extend to at least 6 ft. Table 3 presents some data illustrating podsolization in these sandy soils.

TABLE 3
Profile in deep sand; eroded cliff; NE. coast

	Depth	Colour	Fe ₂ O ₃ %	CaCO ₃ %	Organic matter %	NaCl	pH
A1	10"	Dark Grey	0.05	—	1.2	0.02	4.4
A1	22"	Grey	0.04	—	0.14	0.006	4.4
A2	28"	White	0.08	—	0.15	0.004	5.5-6
B	55"	Red-ochre	0.30	0.2	0.22	0.007	7.0
C	84"	Yellow	0.16	0.2	0.09	0.006	8.0

(NaCl: 0.03 is high, 0.003 normal)

The appearance of the profile is correlated with the height of the dune above sea level, which latter is approximately the level of the fresh water table. When the dune has become stabilized at more than 12 ft above sea level the podsol is ill-defined; the A1 horizon is deep (15") and grades slowly into the grey-white leached layer which is about the same width. The B horizon is not sharply demarcated from either A or C; it is very deep and although the colour is reddish-brown, especially in the vertical channels, the material is not compacted. There is a deep C horizon containing tree roots above the water table.

When the dune has become stabilized at only a few feet above the water table, the profile is typically more podsollic. The grey zone (A1) is less deep (5-12"), the leached zone (A2) is deeper (25") and whiter, and there is sharp transition to the narrow B horizon (6-10"). This is coffee coloured and somewhat compacted. Such variations in profile may occur within a few yards, but they are not reflected in any obvious differences in the vegetation. In three places on the island, only a few feet above sea level, the B horizon is a definite consolidated pan, that in dry weather can only be broken with difficulty by pick or spade. Here, and here only, the dune woodland is replaced by a well-defined heath woodland.

The dune woodland is certainly the oldest stage of the primary succession on the dune ridges, but we are not convinced that it is the climax association. There are indications of a trend towards heath woodland.

Terrace Woodland

On the N. side of all the main dune ridges on Sunday I. there are clearly defined, sandy terraces between the dunes or between dunes and the salt swamps. There is a similar but very narrow terrace on the NE. of the Drum and on the central parts of the small Robert and Gunhammer I. (Fig. 1). The main N. terrace of Sunday I. is up to $3/4$ m. wide. For the greater part, these terraces are flat and aerial photographs show clearly that they are not part of the dune system although there is a gradual transition between them and dunes proper. Their surfaces are up to 4 ft. above high tide level, and they carry what we have called the terrace woodland (Pl. V, fig. 3). On the N. sides, where they adjoin the highest and possibly the climax stage of the salt marsh succession (*Melaleuca ericifolia* scrub), there is usually a clear and steep drop in ground level of about one foot—probably due to wave action at the highest tides.

The vegetation of these sandy terraces resembles that of dune woodland; the dominant tree is *Eucalyptus viminalis*, and the dominant species of the ground flora is bracken. *Banksia serrata* is far less frequent and is absent from much of the terrace woodland. Moreover, the ground flora is much poorer in species (especially woody species) than that of the dune woodland. *Lepidosperma concavum* and the numerous xeromorphic shrubs are rare. Instead there occur such species as *Lomandra longifolia*, *Scirpus nodosus*, *Hydrocotyle hirta*, *Pelargonium australe*, *Senecio lautus*, *S. glomeratus*, *Gnaphalium candidissimum*, *Agrostis avenacea* and, locally, in the damper areas, *Gahnia sieberiana*, *Leptocarpus tenax*, *Juncus pallidus*. There is little doubt that grazing has been more intensive on the terrace than on the dunes, and this is reflected in the presence of alien species, such as *Cirsium vulgare*, *Holcus lanatus*, *Cerastium glomeratum*, *Plantago coronopus*. There are extensive areas of the terraces which are badly drained and in which woodland is replaced by freshwater swamps or open pools.

The surface layers of the soil in the better areas are acid (pH 5.5), of a dark grey sand and there is a slightly podsolc profile. The A horizon is grey or brown, never white. The B horizon is darker brown, very slightly compacted, usually at 16" below the surface and very ill-defined. The C horizon is an uncompacted, yellow-brown sand showing irregular mottling at 3-4 ft where water lies in summer. There is very little clay or silt in the first 3 ft of the horizon, and generally the soil profile resembles that of the dune woodland but appears less mature. It is underlain at 3-4 ft by marine clays with shells, and there is no evidence of the existence of old clay- or peaty-soils resembling those of the salt marshes. For this reason we abandoned an initial hypothesis that the terraces were derived from salt marshes. As indicated in our section on the physiography, we still believe that these terraces were formed either by an uplift of the land or by a fall in sea level (Fig. 2), but we conclude that they were originally sandy, unvegetated flats exposed only at low tide. Aerial photographs show that such a low-flying flat exists at present on the landward side of Clonmel. Leaching has been less pronounced than in the older and higher dune ridges. The vegetation today resembles that of Zone 5 of the dune succession, but is poorer in species, especially those which are indicative of a trend to heath woodland. The early stages of plant succession on the terraces can only be surmised, although it is perhaps significant that the central terrace of Gunhammer I. carries tall *Leptospermum laevigatum* instead of *E. viminalis*.

Heath Woodland

One of the more interesting features of Sunday I. is the existence, admittedly in small areas only, of a damp heath woodland community. The best example occupies 2 or 3 acres in the SW. of the island (Fig. 3, site A). Other examples were located at sites B and C, but these had been recently burned and they will not be described in detail.

A species list (Table 1) does not, by itself, bring out the very striking difference in the aspect of heath woodland and the dune woodland (Pl. V, fig. 1, 4). In both communities the co-dominant trees are *Banksia serrata* and *Eucalyptus viminalis*, which do not form a closed canopy. The heath woodland is immediately recognised by the dominance of *Leptospermum juniperinum* in the shrub layer, the almost complete absence of *Pteridium* and the greater abundance of xeromorphic shrubs. At site A these are mainly *Hibbertia acicularis*, *Acacia verticillata*, *Amperea xiphoclada*, *Acrotriche serrulata* and *Astroloma humifusum*. In addition there are the characteristic heathland species *Euphrasia collina*, *Xanthorrhoea minor*, *X. australis*, *Calorophus lateriflora* and 2 other species, *Casuarina pusilla* and *Banksia marginata*, which, as far as we could ascertain by extensive search, are restricted to the heath woodland and occur nowhere else on the island.

The community at A is typical of the widespread, damp heath woodland of Victoria, although it lacks some of the characteristic species generally present in the more extensive mainland examples, including some species which are present but infrequent in Zone 5 of the island dune succession. The 3 sites (Fig. 3, A, B, C) were all similar in being confined to low-lying parts of the island and in having a highly podsolized soil profile with a true hard-pan ('coffee rock') in the B horizon. In winter the waterlogged pan is fairly easily cut with a spade, but in summer a pick is required to break through it. It has already been pointed out that the B horizon of the dune woodland varies a good deal in its width and compactness. In most of the lower parts of the dunes, where the B horizon must have developed near the winter water table, it is narrow, obvious and compacted, but never rock-like. In higher dunes, this horizon is deeper, much wider and hardly compacted at all. Only in those few places where the B horizon has become hard and rock-like is there a characteristic heath woodland developed.

Numerous soil pits were examined in various parts of the island before this conclusion was reached. 13 of them were dug along the line transects leading out from the heath at A (Fig. 3) to the nearby dune woodland and marsh. All pits dug in the heath woodland or on its extreme margin showed the existence of a hard pan at a depth of about 26". Only a few feet outside this margin there was slight concretion but no continuous hard pan. Within 100 yds of, and outside the heath margin, in *Eucalyptus* woodland with bracken, and in a marshy area with *Gahnia* and *Leptospermum juniperinum* but no typical heath plants, there was leaching and some deposition between 10" and 30", but the B horizon in all these places was not compacted and was lighter in colour than the 'coffee rock'. Well-marked hard pan was found in the profiles under sites B and C.

In the heath soils investigated the pH range in the profile was from 4 (A horizon) to 5 (C horizon). As shown in Table 3, the typical dune woodland soil is only slightly less acid in the surface layers (pH 4.5), but ranges to pH 8 in the deeper layers of the C horizon. There are also undoubted differences in soil fertility between heath and dune soils. Tomato seedlings were grown in surface samples of both soils, each with a pH of between 4 and 4.5. Those in the heath soil

developed very poor root systems and had thinner stems than the others. The growth in height was poor in both tests, but after some weeks the plants of the heath soils had a mean height of only half that of the other set (9.4/18.2"), the difference being statistically significant. There seems little doubt that the heath soils are much more heavily leached than those of the dune woodland.

It is impossible to decide whether the 3 small areas of heath woodland on Sunday I. are derived, after extensive leaching, from low-lying dune woodland or from terrace woodland. All 3 sites are on the boundaries where the 2 communities meet (Fig. 3). A levelling survey showed that at site A the soil surface is 2 ft above high water mark. On its E. side it is bounded by dune woodland rising to 8 ft above high water mark. On its W. side it adjoined one of the treeless and more swampy parts of the terraces. Sites B and C, both damaged by fire, are also low-lying areas adjacent to both dune and terrace. The only reason for assuming that heath woodland is more closely related in origin to the dune succession is the fact that heath species occur sparingly in dune woodland but are absent from terrace woodland.

Elsewhere we shall discuss the possibility that dry heath woodland and dry heath are climax communities of the coastal dune succession, but with *Leptospermum myrsinoides* rather than *L. juniperinum* as a dominant shrub. The former species is very rare on Sunday I. and, although it occurs, with a number of other heathland species in the E. dune ridges, a thorough search has failed to reveal the existence of even tiny patches of heath woodland or of treeless heath on the higher dunes. In view of the relatively light and sporadic incidence of fire on the island, and the fire-resistant properties of the heath species, it appears to us most unlikely that this absence of dry heathland today is due to its destruction by fire and competition by bracken. The soil profile throughout Zone 5 of the dune sere is markedly less leached, and the B horizon less well developed than is usual in Victorian heathlands. We conclude that the dunes on Sunday I. are not yet old enough to develop a heath vegetation, except in those low-lying regions (at sites A, B and C) with a high and variable water table, where leaching has been severe.

Acknowledgements

The authors wish to acknowledge the assistance of all those members of the McCoy Society of the University of Melbourne who took part in the two major expeditions. Our thanks are also due to Mr Stockwell and Mr Robertson of Port Albert, to the Tanbark Development Syndicate for permission to work on the island, to Mr and Mrs Lane and Mrs Fitcher, to Dr F. Loewe for meteorological data, to Miss Joyce Wood for the preparation of the figures, and to Mr J. H. Willis of the National Herbarium for checking the plant determinations.

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Explanation of Plates

PLATE IV

Fig. 1—Zone 1, Clonmel. Embryonic dune, sand-binding by *Festuca littoralis*. The berm is seen in the background with the early stages of new embryonic dunes.

- Fig. 2—Zones 1-3, Clonmel. Fore dune in foreground, with *Spinifex* runners. *Acacia* invading from Zone 3 on R. Embryonic dunes in background.
- Fig. 3—Zones 2 and 3, Clonmel. *Spinifex* on fore dune with *Acacia* invading from Zone 3, R.
- Fig. 4—Zones 2 and 3, Clonmel. View over fore dune to dune scrub. *Spinifex* in foreground. In background, closed dune scrub with *Acacia*, *Olearia* and *Helichrysum*.

PLATE V

- Fig. 1—Zone 5, Sunday I. Typical dune woodland on SW. ridge near the settlement. *E. viminalis* with *Banksia serrata* on R. Ground flora dominated by *Pteridium* and *Lepidosperma concavum*. Scattered shrubs of *Monotoca* are visible.
- Fig. 2—Zone 5, Sunday I. Typical soil profile of dune woodland. The vertical ruler is 2 ft long. Leached horizon (A_2) obvious. B horizon wide and diffuse with vertical pipes. Note secondary deposition of sand above the dark A_1 horizon.
- Fig. 3—Terrace woodland, Sunday I. Flat terrace on N. coast, with *Pteridium* and *E. viminalis*, partly cleared in foreground.
- Fig. 4—Heath woodland, Sunday I. Site A Fig. 3, showing tall unburnt *Leptospermum juniperinum* the dominant shrub with *B. serrata* R, L, middle foreground, *E. viminalis* back centre. *Pteridium* almost absent but one frond shows in centre foreground.





A DISEASE OF PELARGONIUMS CAUSED BY *XANTHOMONAS PELARGONII*

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[Read 13 July 1961]

Abstract

A study of bacterial blight of pelargoniums in naturally and experimentally infected plants is reported.

The causative organism *Xanthomonas pelargonii*, hitherto not described in Australia, was isolated. The cultural, biochemical and antigenic characteristics of the bacterium are presented.

Introduction

Symptoms of blight were observed in pelargoniums (*Pelargonium hortorum*) in July 1958, and in July and November of the following year. The plants were potted cultivars 'Reverend Atkinson' and 'Lady Ilchester' grown from cuttings originally obtained from the Royal Botanic Gardens, Melbourne, and from a commercial firm in New South Wales. The symptoms of the disease indicated the possibility of an infection with *Xanthomonas pelargonii* (Brown) Starr and Burkholder.

A perusal of literature reveals that diseases of pelargoniums have been described by a number of workers, and Hellmers (1952) presented a short history of those investigations. According to records, as far back as 1884, a disease of pelargoniums in France was suspected to be of bacterial origin. Hellmers (1952) in Denmark was able to prove that two different syndromes, namely stem lesions described by some as 'bacterial stem rot of pelargonium' and leaf spots observed by other workers as 'bacterial leaf spot of pelargonium', can be the expression of an attack by the same pathogen, namely *X. pelargonii*.

According to a recent publication (New South Wales Dept of Agric. 1959) 'Geraniums known to the botanist as species of *Pelargonium* . . . have found favour once more'. The re-appearance of those plants in gardens focussed attention on diseases affecting them under local conditions. Apparently in recent years, a bacterial disease of pelargoniums has been noticed in Victoria (Harrison, personal communication) and it is believed that the disease has been present in New South Wales since 1955 (Sutton, personal communication).

As no published records of the isolation in Australia of the causative organism were found, a detailed study was made of the disease under local conditions.

Symptoms in Naturally Infected Plants

Early in the disease, large brown to black lesions appeared on the basal part of the main stem, while the higher part looked dry, shrunken and hollow and had a 'corrugated' appearance. The terminal part of the stem and the petioles seemed at first unaffected but the basal leaves withered. At a later stage, as the infection spread upwards to the tip of the stem, the petioles and the stem developed a brown

discolouration, while the leaves blackened and gradually fell off. The whole plant was stunted and finally withered.

The root system, although dry and discoloured, seemed to be the least affected part of the plant.

Careful examination of naturally infected plants failed to reveal the presence of distinctive leaf spots usually associated with pelargonium blight.

Bacteriological

MATERIALS AND METHODS

For the isolation of the organism plants in the early stage of the disease were chosen. The stem slightly above a black lesion was washed with 10% mercuric chloride, then with 70% alcohol, followed by a few washings with sterile tap water. Isolations from scrapings of the tissue or from the sap were made by plating on brain-heart agar ('Difco' product) or potato-dextrose agar and on wort agar.

After isolation, the cultures were maintained at 4°C on brain-heart agar under paraffin oil and on Dorset egg medium in screw capped Bijou bottles which were firmly closed after abundant growth was obtained. Subcultures were made approximately every 2 months. Biochemical tests were performed as follows:

Carbohydrate fermentations were determined using carbon compounds in a synthetic peptone-free medium (Dowson 1957) observed for 28 days.

Other tests were carried out according to directions given by Mackie and McCartney (1953) unless otherwise stated. The indole test was performed after 7 days, using xylol for extraction. Methyl red and Voges-Proskauer tests were carried out after 4 days incubation at 25°C, and creatine was used in the Voges-Proskauer test. Nitrate reduction was determined in a medium with 0.2% potassium nitrate and the cultures were spot-tested after 1, 2 and 5 days incubation. Hydrogen sulphide production was observed on brain-heart agar using lead acetate paper.

The serological techniques used were those recommended by Kauffmann (1954) except for the method of producing diagnostic antisera, which was according to our own previously described procedure called 'shock treatment' (Mushin, Naylor and Lahovary 1959). Steamed saline suspensions from growth of two isolates on brain-heart agar served as somatic antigens. Prior to injections, the sera of the rabbits were shown to be free of normal agglutinins against the organism under investigation and against the surface antigens α and β (Mushin, Naylor and Lahovary 1959). The somatic antigens were inoculated into the rabbits in 7 intravenous injections each of 0.5 ml within 8 days. The animals were test bled the second day after the final injection and, if the titre was satisfactory, the rabbits were bled out from the carotid artery on the third day. The glycerolated sera were stored at 4°C.

RESULTS

Microscopic examination of hand-cut sections of stem lesions showed the tissue cells to be filled with bacteria but no fungal hyphae were observed.

CULTURAL CHARACTERS: After 48 hours incubation on brain-heart agar the colonies were slightly yellowish, circular and semi-transparent, measuring 1 to 2 mm in diameter. The confluent growth on brain-heart agar was also yellowish, while on potato-dextrose agar the pigment was distinctly yellow and the colonies were mucoid.

MORPHOLOGY: The organism was a Gram-negative rod, $0.5\mu \times 1$ to 1.5μ in size, showing monotrichous flagellation.

BIOCHEMICAL CHARACTERS: Acid was formed in glucose, sucrose and galactose in 3 to 5 days and in lactose after 10 days, while salicin, maltose, rhamnose, mannitol and glycerol were not fermented. Litmus milk was peptonized in 4 days and the surface of gelatin was liquefied in 5 days.

The indole, methyl red and Voges-Proskauer tests were all negative. Urea was either not hydrolysed or very slightly. The citrate test was positive. Nitrate was not reduced to nitrite. Hydrogen sulphide was produced.

SEROLOGY: Glycerolated "O" sera agglutinated heated suspensions of the isolated organism up to a titre of 1280. Slide agglutinations occurred when serum was mixed with saline suspensions of the living bacteria, thus indicating the absence of a mucoid surface antigen which tends to block the reaction.

TABLE 1

Titres of 'O' Agglutination Tests with Unabsorbed and Absorbed Antisera Against X. pelargonii

Antiserum	Titres against suspension of:		
	<i>X. pelargonii</i>	<i>X. campestris</i>	<i>X. phaseoli</i>
Unabsorbed	1280	640(3), 40(1)	160(1), —(3)
Absorbed with suspension of:			
<i>X. pelargonii</i>	—		
<i>X. campestris</i>	1280	—	—
<i>X. phaseoli</i>	1280	—	—

— = Titre < 20. Numbers in parenthesis refer to the number of strains giving a particular reaction.

As shown in Table 1, agglutination tests indicated a close serological relationship between *X. pelargonii* and 3 strains of *X. campestris* and a slight affinity with one strain of *X. campestris*. Antigenic relationship was also demonstrated between *X. pelargonii* and one out of 4 *X. phaseoli* strains tested. 5 other *Xanthomonas* species, namely *X. juglandis*, *X. vesicatoria*, *X. carotae*, *X. incanac* and *X. albilineans*, were not agglutinated by *X. pelargonii* antiserum.

Absorption of the serum by *X. campestris* and *X. phaseoli* antigens did not lower the titre of *X. pelargonii* antiserum against its homologous antigen, showing the presence of an additional major antigenic factor in the structure of *X. pelargonii*.

Plant Pathogenicity Tests

METHODS OF PROPAGATING TEST PLANTS

Cuttings were taken in the autumn from healthy pelargonium plants (*P. hortorum*) which had shown for several seasons normal growth cycles. The base of each cutting was dusted with a rooting powder containing 5 p.p.m. indole butyric acid and they were inserted into a medium made up of equal parts of standard grade vermiculite and perlite, both products being of local manufacture. The medium was contained in new flats which were treated with copper naphthleneate to inhibit fungal growth and the foliage was sprayed with systemic insecticide.

After development of sufficient root system, the test plants were placed in 3½" terracotta pots. These contained washed river sand obtained locally from Fisherman's Bend, granulated peat from West Germany and fertilizer. The plants were watered individually with a can and no 'bottom soaking' was employed.

EXPERIMENTAL INFECTION OF PELARGONIUM PLANTS

Two series of experiments were set up. Various cultivars of *P. hortorum* were used, namely 'Lady Ilchester', 'Reverend Atkinson', 'Welcome', 'Festival', 'Plum Rosebud' and 'French Bouquet'.

In the first set of experiments 9 plants were placed in moist chambers in a glasshouse regulated at 25°C for 24 hours before and after inoculation. 6 plants were inoculated into the stems, using a needle dipped in a thick saline suspension of the test organism grown on moist brain-heart agar for 48 hours. 3 control plants were pricked with a sterile needle.

After 2 weeks, the inoculated plants showed water marks and 'corrugated' lines on stems (Pl. VI, fig. 1, 2). 2 weeks later, the symptoms were more pronounced, a dry type of rot was evident and the plants were slightly dwarfed beside the controls (Pl. VI, fig. 3). 6 weeks after the inoculation, the stems had rotted and the leaves were withered, but at no time were any distinct leaf lesions observed. The inoculated organism was recovered from the stems in pure culture.

Another series of experimental infection of plants was set up in summer, at the end of December. Here the procedure of inoculation differed slightly in that a small gauze plug, dipped in a bacterial broth culture was inserted into a needle puncture in the stem. This provided a reservoir of the organism and protected from drying (Kivilaan and Scheffer 1958). 9 inoculated plants and 3 controls were covered with gauze and placed in 2 separate groups out-of-doors in a shaded area of the garden.

Records of temperature and humidity readings at 9 a.m., 3 p.m., and 9 p.m. were obtained during a 3-week period of observation.

TABLE 2
Temperature and Humidity Records during an Out-of-doors Plant Inoculation Test

Time	Temperature °F		% humidity	
	Highest	Lowest	Highest	Lowest
9 a.m.	90	61	84	28
3 p.m.	97	61	94	21
9 p.m.	88	61	77	31

It can be seen that the temperature at times indicated in Table 2 ranged from 61°F to 97°F, while the humidity varied between 21 and 94%.

Within 2 to 3 weeks of inoculation, symptoms of dry brown rot appeared on stems of the infected plants and the leaves gradually withered, but no leaf lesions were evident. The causative organism was recovered in pure culture.

ADDITIONAL TESTS

It was desirable to confirm the identity of the isolated organism, suspected of being *X. pelargonii*, by comparing it with a type culture. Australian quarantine regulations do not permit the importation of cultures of plant pathogenic bacteria not known to be already established in this country. Therefore, arrangements

were made for our cultures to be examined by two overseas authorities. Dr D. W. Dye of Auckland, New Zealand, and Professor A. W. Dimock of Ithaca, U.S.A., both confirmed the identity of the bacterium as *X. pelargonii*.

Additional information was given by Dr Dye who used our isolates to inoculate plants under environmental conditions different from those in our experiments. Young leaves of actively growing plants were inoculated with broth cultures of our isolates. The plants were placed in a temperature-controlled cabinet in which sufficient water mist was supplied to keep leaf surfaces wet without considerable run-off (Dye, personal communication). Under those conditions, leaf spots were obtained in the form of angular to roughly circular water-soaked areas sometimes surrounded by a yellow halo. Later the lesions became brown to black in colour and dry (Pl. VI, fig. 4).

Conclusions

From the description of the bacterium and the blight symptoms reproduced in host plants it was concluded that the organism described is *X. pelargonii*. Therefore the disease is apparently endogenous in Australia.

Discussion

It was shown (Kivilaan and Sheffer 1958) that various factors may affect the development of bacterial stem rot (bacterial blight) of pelargoniums. Under our local conditions the stem rot was observed and was easily reproduced by infecting healthy pelargonium hosts with *X. pelargonii*. Leaf spots were not reported in naturally infected plants but they appeared in New Zealand in plants inoculated with our isolates under favourable conditions of high humidity. The morphology, cultural and biochemical characters of the isolated strain of *X. pelargonii* were similar to those described by other workers. A minor difference was noticed in the failure of the local strain to ferment glycerol as described by Hellmers (1952), while mannitol fermentation is apparently variable (Starr, Volcani and Munnecke 1955).

It was of interest to compare the results of our serological tests with those performed by Elrod and Braun (1947A). Their technique differed in that living bacteria were used as antigens and the mucoid material was extracted from the cells with warm saline. In their grouping of *Xanthomonas* species based on antigenic structure, *X. pelargonii* was placed in a group of strains related to *X. campestris* and *X. phaseoli*.

In our experiments, using steamed suspensions of freshly isolated strains of *X. pelargonii*, the somatic antigens seemed to be devoid of mucoid material. A close serological relationship was shown with 3 out of 4 strains of *X. campestris* and a slight affinity with one only out of 4 strains of *X. phaseoli*. This discrepancy in serological results may be due to differences in strain specificity or in the application of different techniques. Recently, Sloda and Cleverdon (1959) also indicated a serological affinity between *X. pelargonii* and *X. campestris*. The lack of antigenic relationship between *X. pelargonii* and a few other species tested in this study confirms the results obtained by the above workers.

Elrod and Braun (1947B) pointed out the possible discrepancies when species identification is based on results of pathogenicity tests and serological reactions. Dye (1958) has shown that host specificity, on which the classification of *Xanthomonas* species is dependent, may not be a stable character. There seems to be a possibility that further studies of host-parasite relationships amongst plant

pathogenic bacteria may widen the host spectrum of various species, thus undermining host-specificity as the determinative factor in classification within the genus. On the other hand, a thorough bacteriological examination of large numbers of bacterial strains with emphasis on antigenic analysis may provide a sounder base for species identification.

Acknowledgements

The authors are grateful to Dr D. W. Dye, Auckland, and Professor A. W. Dimock, Ithaca, for their contribution in confirming the identity of the locally isolated strains of *X. pelargonii*. Thanks are expressed to Mr S. Ramsey, Auckland, for the photograph of the leaf symptoms. The assistance of the Plant Quarantine Office, Canberra, in dispatching the cultures abroad for examination is appreciated.

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Explanation of Plate

PLATE VI

Fig. 1 and 2—Close-up of a stem of pelargonium (*Pelargonium hortorum*) 4 weeks after inoculation.

Fig. 3—Pelargonium plants (*P. hortorum*): healthy control and 4 weeks after inoculation.

Fig. 4—Leaf spots on pelargonium 6 days after inoculation. Centre top are leaves of *P. peltatum* and lower of *P. hortorum*.



THE OCCURRENCE OF *OTOZAMITES* IN SOUTH-EASTERN VICTORIA

By J. G. DOUGLAS

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[Read 13 July 1961]

Abstract

Leaf impressions referable to the genus *Otozamites* are described from Victoria for the first time.

Introduction

The range of the genus *Otozamites* (Braun), which has not hitherto been convincingly recorded from Victoria (Medwell 1954, Walkom 1921), is extended by this description of specimens from the Boola Boola Forest in SE. Victoria. Two localities closely related stratigraphically in fine-medium grained sandstone contain plant impressions including the *Otozamites* specimens described below. Unfortunately preservation is poor with cuticle absent. A well-exposed Mesozoic section striking NE. and dipping SE. at about 15° and overlying steeply dipping Palaeozoics, consists predominantly of sandstones with a basal conglomerate. Occasional mudstone lenses within the sandstone contain a much larger flora than the sandstone.

CYCADOPHYTA

Order CYCADEOIDALES

Otozamites sp. indet.

(Pl. VII, fig. 1-4; Fig. 1)

DESCRIPTION: The material consists of leaf fragments bearing pinnae with prominent auricles, and with margins sub-parallel to the apex where the lower tapers abruptly to meet a relatively straight upper, to form an acute tip. Venation, distinguishable in few pinnae, consists of 5-6 gently diverging veins entering the whole pinna base. Branching of veins begins half way along the pinna, each arm diverging at about 15°.

DIMENSIONS: Length of leaves—maximum 60 mm (fragments only), average 40 mm; width—maximum 20 mm, average 10 mm. Length of pinnae—average 5 mm; width—average 1.7 mm.

SPECIMENS IDENTIFIED: Reg. No. Geological Survey of Victoria—57745, 57746, 57747, 57748, 57750, 57780, 57781.

LOCALITY: Boola Boola Forest, Locality No. 1 Coordinates Misc. Topo. 83 sheet 4, 3007N, 4471E.

ROCK TYPE: Fine—medium grained yellow brown sandstone.

DISCUSSION: Two genera *Otozamites* and *Ptilophyllum* Morris show to greater or lesser extent the characters described above. The boundary between these genera is somewhat arbitrary (Harris 1949, Jacob and Jacob 1954) and anatomical evidence is lacking, but the material is classified in *Otozamites* because of prominent

auriculated pinnae bases (Pl. VII, fig. 1; Fig. 1) and radiating bifurcating veins (Pl. VII, fig. 3). Reg. No. 57750 (Pl. VII, fig. 4) shows the basal part of the leaf with base somewhat obscured. Both genera sometimes possess basal pinnae varying greatly from those on the remainder of the leaf.

Otozamites anglica (Seward) Harris and *O. bengalensis* Oldham and Morris are most like the Boola Boola material, but the latter differs markedly in gross form and has more veins in the pinna base. The venation of the former is similar to the Victorian specimens, but the pinnae are more widely set apart and of oblanceolate shape. It is felt that the poor state of preservation prevents reliable determination beyond generic status.

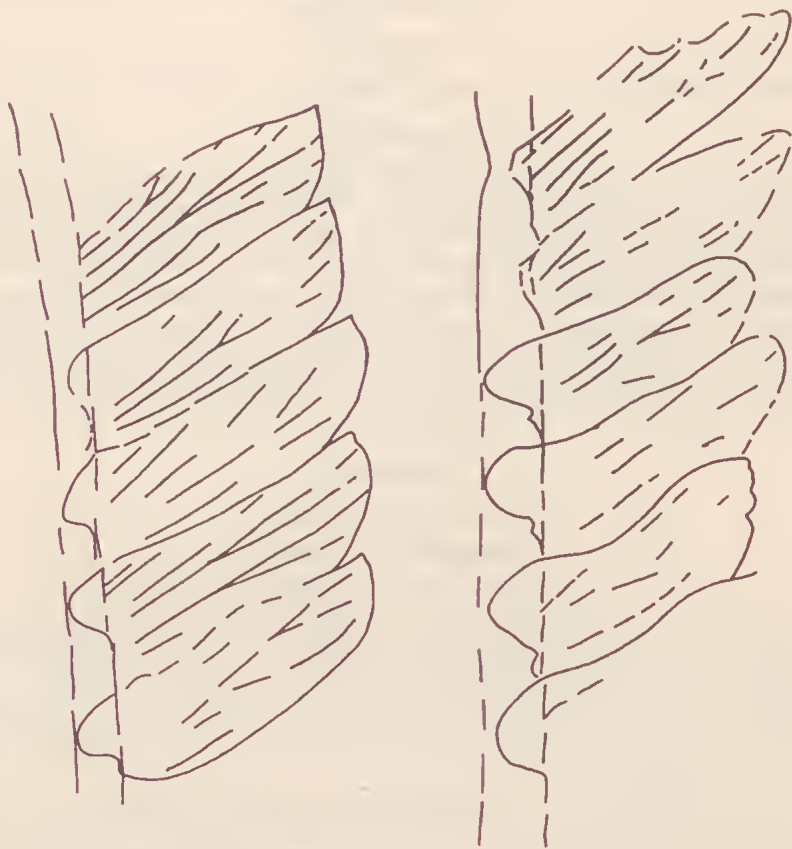


Fig. 1—*Otozamites* sp. indet. Reg. No. 57748 x 6.
Pinnae showing auriculation and remains of venation. Left, from upper portion of leaf.
Right, from lower portion of leaf.

The geographically nearest species *O. bengalensis* is from the Mt Babbage, South Australian beds, dated as Lower Cretaceous (Glaessner and Rao 1955). Medwell (1954) placed all E. Victorian Mesozoic floras in the Lower Jurassic without a critical study of individual assemblages. Cookson and Dettman (1958) on microfloral studies placed beds, higher up the sequence than the *Otozamites* flora, in the Lower Cretaceous.

Ptilophyllum ? sp.

(Pl. VII, fig. 5)

DESCRIPTION: Several fragments, with gross form and pinna base apparently well delineated, show no trace of auriculation. Venation, however, is obscure and no cuticle is preserved.

DIMENSIONS: Length of pinnae—average 4 mm; width—average 1.2 mm.

SPECIMENS TENTATIVELY IDENTIFIED: Reg. No. 57775, 57784, 57783.

LOCALITY: As *Otozamites* sp. indet. above with the exception of Reg. No. 57783 and 57784 from Locality 27 (same coordinates).

ROCK TYPE: As *Otozamites* sp. indet. above.

DISCUSSION: These fragments are tentatively classified as *Ptilophyllum* because there is no trace of auriculation of the pinna base. However, preservation is poor and in view of the intergradation between this species and *Otozamites* identification cannot be carried further.

The *Otozamites* flora is interesting because of its absence from other well-sampled Victorian localities, and apparent absence from nearby mudstone beds. These latter, in contrast, contain large unbroken fronds and an extensive array of delicate fossils. A wide range of explanations can cover this, as the deposition of plant remains, particularly under rapid depositional conditions as envisaged by Philip (1958), is a highly complex subject (Black 1929), depending on vicissitudes of sedimentation and palaeoecology.

Acknowledgements

I am indebted to Dr J. A. Townrow, University of Tasmania, for valuable comments on this and other palaeobotanical work.

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Explanation of Plate

PLATE VII

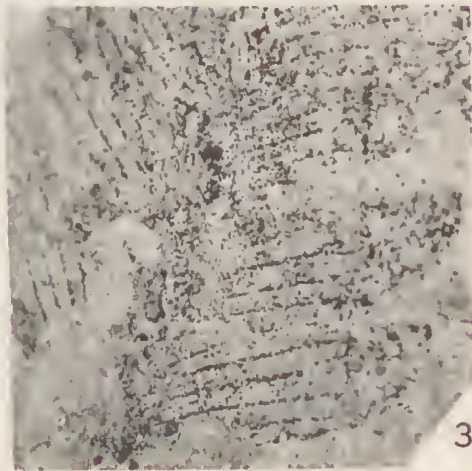
Fig. 1—*Otozamites* sp. indet. Reg. No. 57748 x 3.

Fig. 2—*Otozamites* sp. indet. Reg. No. 57746 x 2.

Fig. 3—*Otozamites* sp. indet. Reg. No. 57746 x 7.5 (Immersed in xylol). Pinnae showing venation.

Fig. 4—*Otozamites* sp. indet. Reg. No. 57750 x 5. Base of leaf.

Fig. 5—*Ptilophyllum*? sp. Reg. No. 57775 x 2.



GRANITE ISLANDS OF SOUTH-EAST VICTORIA AS A SEABIRD HABITAT

By MARY E. GILLHAM*

*Working in conjunction with the C.S.I.R.O. Wildlife Survey Section
[Communicated by J. A. Thomson 13 July 1961]

Summary

The principal rookery plants are halophytic, succulent creepers and tussocky monocotyledons, mainly *Poa poiformis*. Bracken and shrubs are less common. Penguins and shearwaters and other petrels burrow most plentifully in conditions of medium to great exposure; under rigorous exposure soil depth and vegetative cover are insufficient; in calm areas plant growth is too lush. The optimum burrowing medium is fairly sandy but not too mobile. Where lack of soil or unsuitability of soil texture makes burrowing impossible, birds may live under particular kinds of herbage.

The open vegetation and friable soils of mutton-bird rookeries constitute an ideal habitat for rabbits, but summer suppression of plants by the birds in the drier areas exerts a seasonal check to their numbers. A small rabbit population can complete the summer destruction of practically all vegetation except coarse, unpalatable tussocks and composites. On Rabbit I., where this had occurred, hundreds of mutton-birds died in the anomalous heat wave of January 1959. On ungrazed islands nearby the burrows were shaded by vegetation and there were few or no casualties. Serious predation by foxes occurs on Benison I., and the Gabo I. mutton-birds have been reduced to a fraction of their former numbers by feral cats.

Smaller petrels burrow among *Poa* on 2 of the Glennie I., and penguins occur on all but the 3 most sheltered islands in Corner Inlet. Silver gulls nest on 3 islands, their presence stimulating the succulent-leaved *Disphyma australe*, *Carpobrotus rossii* and *Lepidium foliosum*. The latter dominates a roost of black-faced cormorants on Granite I. where the ornithocoprophilous alga *Prasiola stipitata*? is frequent and constitutes the second record for Australia. Destruction and replacement of vegetation occur near ground-roosting and tree-roosting cormorants on Doughboy I. Cape Barren geese graze the Glennie Group, eating mostly *Disphyma australe* in the dry summer period.

Introduction

Descriptions of the 9 granitic islands that have provided data for this paper and lists of the vascular plants, bryophytes, and seabirds have been published elsewhere (Gillham 1961a).

Although the islands are edaphically similar, their degree of exposure to spray-bearing winds varies widely. Most exposed is the Glennie Group off the SW. tip of Wilson's Promontory (Citadel I., Dannevig I. and McHugh I.). Most sheltered are Doughboy I. and Benison I. in the muddy inner part of Corner Inlet N. of the Promontory. Between these two extremes are Cliffy I., 20 m. S. of Port Albert and 12 m. E. of Wilson's Promontory; Rabbit I., near the E. side of the Promontory, and Granite I., near the mouth of Corner Inlet (see locality map, Gillham 1960a).

Gabo I., 320 m. ENE. of the Wilson's Promontory islands near the Victoria-New South Wales border, is larger than the others, is composed of medium-grained red granite instead of porphyritic grey granite, and is the only one of the 9 to possess sand dunes and heath vegetation.

This paper deals with the principal environmental factors affecting the nesting and roosting habitats of the vast populations of seabirds that inhabit the islands

and some of the ways in which the vegetation and soil affect the birds. Ways in which the birds affect the vegetation and soil are dealt with in a previous work (Gillham 1960a).

Most of the observations made apply equally well to Bass Strait rookeries farther S., in the Furneaux, King and Hunter groups of islands, except where the vegetation of these is periodically destroyed by burning, as on most of the commercial mutton-bird islands. Only in the higher rainfall areas of S. Tasmania and the hotter, drier climates to the N. of the region under consideration do conditions in the rookeries become materially different.

Typical Rookery Vegetation in Colonies of Burrowing Birds

In order to survive the rigours of seasonal occupation by birds, plants of the rookeries need to be resistant to heavy trampling, to introduction of atmospheric conditions underground in burrows, and to a high concentration of soil nutrients arising from guano deposition.

Most of the indigenous coastal heath plants are unable to cope with these conditions and give way to others that appear fairly constantly in rookeries from S. Tasmania to the New South Wales border—many of them also in New Zealand rookeries. The plants that persist best are often those that are also able to survive the soil disturbance of storm-swept, eroding coasts and the high concentration of soil salts arising from the deposition of seaspray. This results in the occurrence of coastal plants away from the coast and is especially well seen on Gabo I., where pockets of *Carpobrotus rossii* dotted through the inland scrub are indicative of out-lying parts of the penguin colony. This phenomenon is seen also on British bird islands (Gillham 1956b).

Poa poiformis is the most widespread rookery species in SE. Australia and has a growth form that necessitates the birds going round the tussocks rather than over them, so that it suffers little suppression from trampling after the initial stages of growth. In densely populated rookeries the tussocks are widely spaced and the highways between them are worn bare of plants during the height of the nesting season. An analogy can be drawn with the dominant *Armeria maritima* of British shearwater rookeries, where burrows penetrate beneath the stabilizing mounds and tracks lead between them (Gillham 1956a).

Other tussocks providing similar habitat conditions on the Victorian islands are *Lepidosperma gladiatum*, *Lomandra longifolia*, *Scirpus nodosus*, and *Stipa teretifolia*.

Next in importance to the tussocky monocotyledons are the succulent creepers, principally members of the Aizoaceae (*Carpobrotus rossii*, *Disphyma australe*, *Tetragonia implexicoma*). Their creeping habit and method of anchorage enable them to withstand localized disturbance by burrowing. The high water content of the leaves serves to dilute excessive amounts of internal salts arising from concentration of the soil solution by guano, and also acts as a guard against wilting in habitats where air temperature and humidity in burrows among the roots may approximate to those of the atmosphere. Even so, both *Carpobrotus* and *Disphyma* were severely wilted on the Corner Inlet islands after an exceptional heat wave in January 1959.

Another important division of rookery plants might be termed 'bird evaders' in that they 'cash in' on the stored nutrients in otherwise unvegetated soil during the winter when the birds are at sea, but usually succumb to bird pressure and

die during dry summers. These fall into two groups, exemplified on the one hand by small ephemeral grasses and caryophyllaceous plants, and on the other by more sturdy composites.

Most traces of the former group become obliterated by the end of the summer, but the stark remains of members of the latter group persist. The most conspicuous example on the SE. Victorian islands is the dead *Carduus tenuiflorus*, which forms open but almost pure stands in the Doughboy I. rookery from mid-summer onwards.

The tall inland form of *Senecio lautus* with finely divided leaves is common on the 3 sheltered Corner Inlet islands and in the protected N. valley of Rabbit I. It, too, died off in 1959, although it is usually perennial where unaffected by soil guano. The more usual bird-colony type, a short maritime form with very succulent, serrated or entire leaves, is very resistant to guano and able to persist throughout the breeding season. Some plants behave as perennials, others as annuals, but the autumn crop of seedlings becomes established while the young birds are still in the burrows.

Other composites coming into this division during hot dry summers but often persisting in cooler, moister seasons are *Cirsium vulgare*, *Helichrysum bracteatum* v. *albidum*, *Hypochoeris glabra*, *Leontodon hirtus*, *Senecio minimum*, *Sonchus asper* and *S. oleraceus*, and, on Victorian and Tasmanian islands other than the 9 under consideration, *Erigeron bonariensis*, *E. canadensis*, *Senecio capillifolius*, *S. glomeratus* and *Silybum marianum*. Not all of these behave as annuals, *Helichrysum* usually dying back only to ground level, even in a drought year, and *S. capillifolius* being more often biennial.

All the above genera (apart from *Helichrysum*) are represented in British rookeries, some by the same species; *Cirsium vulgare*, *Sonchus asper*, and *S. oleraceus* are particularly widespread. The most characteristic *Senecio* of British rookeries is the ragwort, *S. jacobaea*.

The prevalence of members of the Compositae in rookeries is probably related to the large area of bare soil, which offers ample space for the establishment of the efficiently dispersed disseminules. It is not uncommon to see clouds of thistle-down, with or without attached seeds, drifting several miles out to sea and covering areas of several acres. The islands in the path of these clouds that show the most severe infestation, possibly only a year after being practically free from the species, are those where soil has been bared by bird traffic or overgrazing (assuming, of course, that adequate shelter is available).

Two important coastal life forms less characteristic of rookeries are bracken and shrubs. The interlacing underground rhizomes of *Pteridium esculentum* are an important deterrent to burrowing birds, which normally occupy only the sparser stands.

Burrows usually diminish beneath shrubs, particularly those of very exposed conditions where stunted branches form impenetrable ramifications close to ground level. Open-floored scrub is preferred and may be occupied as long as there is ready access to the sea, but the short-tailed shearwater is not found so typically in scrub as are species of the Queensland coast and New Zealand. Soft-leaved shade plants and sclerophyllous shrubs are easily destroyed by birds, so, when once established, the birds help to maintain an open ground layer beneath the trees.

Leptospermum laevigatum, a plant of both cliffs and dunes, is one of the most abundant rookery shrubs. Other important species are *Correa alba* and *Melaleuca ericifolia*. Frequently burrows in scrub are accompanied by growths of the succulent coprophiles, *Carpobrotus rossii*, *Rhagodia baccata* and *Tetragonia implexi-coma*. These trail up through the branches of the shrubs, partially smothering the photosynthetic surfaces and probably hastening the degeneration already initiated by salt-bearing winds and bird damage (see Gillham 1960a).

Fig. 1 illustrates the principal plants in one of the most modified types of rookery and in one of the least modified. The histogram shows the percentage ground cover of plants on a belt transect across the sheltered top of Doughboy I. in Corner Inlet.

Excluding the portion beneath a clump of *Eucalyptus viminalis* trees, the first 28 metres of the transect were heavily burrowed by mutton birds. A lot of dark sandy soil with flakes of guano and granite chips in the surface layer was exposed and the vegetation was entirely altered. The dominant plant was the introduced *Vinca major*, the most generally distributed subordinate *Carduus tenuiflorus*, and the only other species of any importance *Senecio lantus*.

This area was fairly level and on deep soil with no outcropping rocks. Because of the open nature of the vegetation and the general collapsibility of the soil, frequent repairs to burrows were necessary and none of the area remained free from the effects of excavation.

The cliff face rookery depicted in the last 6 metres of the transect consisted, on the other hand, of scattered burrows penetrating deeply beneath large boulders and scarcely affecting the scanty patches of vegetation between. Most of the area consisted of bare rock, and the only important plants were *Acaena anserinifolia* and *Pteridium esculentum*. Where burrow density increased on this cliff so also did *Vinca major*.

These two types of rookery were separated by a granite shoulder, where the soil was too shallow for burrowing. It was dominated by *Correa alba* in the rockier parts and by *Acaena* and small pasture species elsewhere.

Effect of Wind Exposure on the Burrowing Habitat

EXCESSIVE EXPOSURE

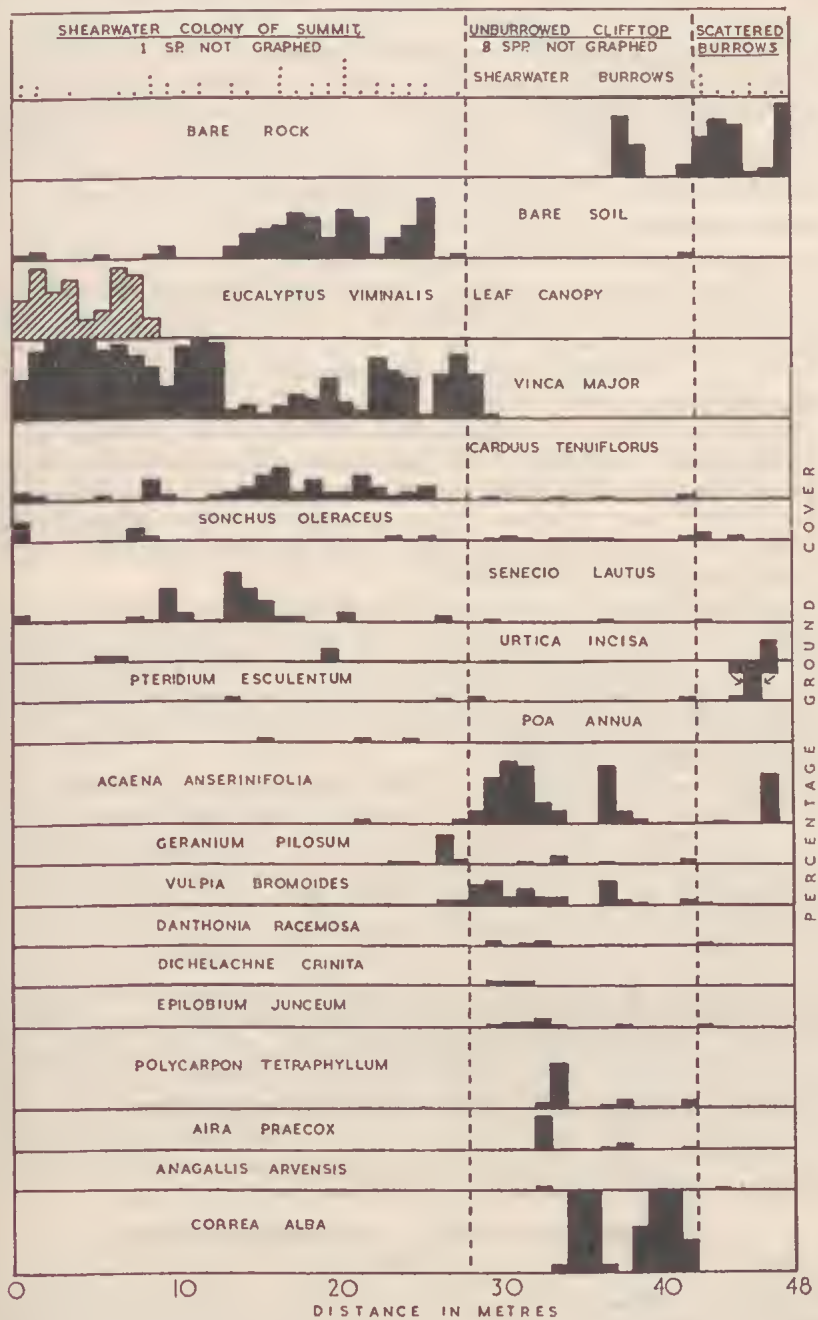
The range of exposure suffered in rookeries is wide, but the optimum appears to lie in fairly oceanic conditions where exposure could be classified as 'medium to great'. Where it is excessive the habitat becomes unsuitable.

On Citadel I., which is fully exposed to the S. and W., practically all soil has been swept into the sea during storms. The plants that survive the rigours of the habitat are too sparse and stunted to give cover to birds nesting without burrows, and the only suitable nesting sites are in rock crevices—situations favoured more by penguins than by mutton-birds.

Mutton-birds have had little more success on the exposed parts of Dannevig and McHugh I., where attempts to burrow in too shallow soil and too sparse vegetation are doomed to failure in consequence of frequent collapse of the thin burrow roofs.

In such areas an expanding colony of mutton-birds, with need to utilize every available nesting site, contributes in no small measure to the destruction of its own habitat, the burrowed soil eroding much more easily than the unburrowed.

Fig. 1—Doughboy I., Corner Inlet, 16 January 1959. Transect from SW. to NE. across summit colony of shearwaters to unburrowed clifftop with scattered nests below; 48 x 1 metres.



Sparse recolonization by plants helps to build up the level again, but the process is slow and subject to periodic catastrophies, so that completion of the cycle to bring the area back into the rookery takes a very long time.

The importance of adequate cover is well illustrated on the Clifly I. Group, about 20 m. S. of Port Albert, which is almost as exposed as the Glennie Group. Soil and vegetation are sparse on Notch I. and White Rock, and mutton-birds are scarce or absent; adequate amounts of cover are confined on Clifly I. to the small area on the summit where the birds congregate, and both soil and plants are more abundant on Rag I. and Seal or Direction I., where mutton-birds are reported to be numerous.

EXCESSIVE SHELTER

At the other extreme are some localities on the Victorian islands that are too sheltered for adequate burrowing. In these a soft, lush vegetation excludes the birds from the burrowing medium and fails to attract them into the cover of its foliage as do more rigid xero-halophytes—possibly because of its greater power of surface water retention, possibly because of the stronger, more continuous growth, which obliterates all traces of nesting sites soon after they are vacated.

Both Doughboy and Benison I. are unusually sheltered for mutton-bird colonies and possess areas of dense vegetation untenanted and probably untenable by birds. Rookeries are common on the mainland coast of Tasmania, but all of those visited were adjacent to much more turbulent waters than the shallow, mud-floored, inner portion of Corner Inlet.

Of over 80 rookeries visited around Tasmania and Victoria only a small proportion occur on sand dunes, and these are almost exclusively on the mainland or larger islands. Mutton-birds of these inevitably more sheltered situations attain the necessary openness of vegetation as a result of edaphic rather than climatic factors. Where dense creepers occur locally it is not uncommon to find dead birds trapped among the tangle of stems.

On Benison I., where there are no dunes, the rookery is confined to the more exposed W. slopes. On Doughboy I. the main part of the rookery is so populous that most of the native perennial vegetation has been killed and much of what remains is transient, dying away in summer.

Examples could be cited of closely related shearwater species burrowing successfully in dense bush communities, but the density in these instances is of the tree canopy rather than of the plants in the vicinity of the burrows. The denser the canopy the greater is its capacity for shading and inhibiting the ground flora.

Thus the wedge-tailed shearwater (*Puffinus pacificus*) burrows in thick *Pisonia grandis* forest on islands of the Great Barrier Reef, where the coral sand beneath may be bare or covered by a 'leggy' growth of *Abutilon indicum*, *Euphorbia heterophylla* or *Wedelia biflora*. The sooty shearwater (*Puffinus griseus*) burrows in the soft peat beneath mixed evergreen bush on small islands off Stewart I. in S. New Zealand, where again the ground may be bare or occupied by open growths of large ferns, principally species of *Asplenium* and *Blechnum*.

Importance of Soil as a Burrowing Medium

SOIL MOBILITY

The degree of soil mobility, as already indicated, has an important bearing on the longevity of rookeries on cliffs. It is an even more potent factor on dune sand, where burrow roofs collapse with extreme facility unless the sand is firmly bound

by plant roots or rhizomes. Birds are unable to colonize the more mobile dunes, but occur beneath pioneer dune species such as *Ammophila arenaria* in fairly well vegetated regions.

The only mutton-birds in dune sand in the areas under consideration are a sparse population on Gabo I. and a few isolated pairs in the sand-filled valley of Rabbit I. Their relative scarcity in the latter, in spite of the fact that the remainder of the island carries a population close to saturation point (an average of about 2 burrows per sq. metre over the whole and up to 5-6 per sq. metre), is witness to the birds' inability to keep the burrows open in this type of substrate.

The extensive low sandhills that form the main part of the penguin rookery on Gabo I. are relatively stable and almost completely vegetated, except at burrow entrances and in the localized blowouts. The plant succession has passed the pioneering tussock phase and entered the stabilizing mat phase, and the dominant *Carphobrotus rossii* and locally dominant *Stenotaphrum secundatum* are among the most efficient of mat formers. Collapsed and silted burrows border the blowouts, and the opening out of the plant mat by the penguins has undoubtedly aggravated and probably initiated the erosion of these.

Where soil mobility on cliffs is accentuated by steepness of slope the birds insinuate their burrows beneath any available stabilizing agents such as tussocks, roots of isolated shrubs, or boulders.

SOIL CONSOLIDATION

Just as considerable exposure, but not too much, is beneficial to burrowing birds, so is a high proportion, but not too much, of the mineral fractions contributing to soil friability. Too great a percentage of the clay and silt fractions facilitates 'poaching' to give a hard unburrowable surface and decreased permeability, so that burrows are liable to become waterlogged. It is well known that rabbits avoid the heavier clay soils. Shearwaters avoid them even more rigorously, but are not averse to taking over rabbit burrows in areas where it is improbable that they could have excavated their own.

No burrows were found on the partially waterlogged peat areas of Gabo I., although sooty shearwaters burrow freely in the peats of S. New Zealand and Macquarie I. Elsewhere all the SE. Victorian soils are freely draining sands with relatively small amounts of organic matter, offering no obstacle to burrowing birds.

Trampling by farm livestock may intensify the degree of consolidation to the detriment of the birds, but on Gabo I., the only one of the 9 islands on which stock were present, the rookeries are located on coarse 'unpoachable' sand, where the large particle size ensures a large pore space between. On such soil the trampling of dung and herbage into the surface layers is likely to be beneficial rather than otherwise.

NESTING SITES OF BURROWING BIRDS ON UNBURROWABLE SOIL

Numerous abortive attempts at burrowing were seen, the tunnels ending blindly against solid granite 30-40 cm from the entrance. Penguins not infrequently manage to rear chicks in these truncated burrows, but shearwaters sheldom seem to. It is problematical whether a second attempt is ever made at burrowing, and deserted eggs in inadequate holes were still fairly common at the end of January

1959, although most would have been taken by gulls and other predators soon after being laid about the last week of November.

It is in such localities that the more diffuse protection of herbage has often to suffice as a concealment for the nesting chamber, and it is as well for the occupants that trampling by farm livestock is not one of the habitat factors on the islands where such conditions occur.

In the most exposed areas, notably on Dannevig I., curtains of *Disphyma australe* draped across rock crevices give adequate protection to nesting birds, with *Tetragonia implexicoma* serving a similar function in areas of local shelter. With slightly mitigated exposure, as on the summit of Clifty I., eggs are laid beneath the arched leaves of *Poa poiformis* tussocks. The larger tussocks of the more maritime *Stipa teretifolia* are also utilized, particularly by penguins.

With increased shelter, as on Granite and Benison I., birds insinuate themselves beneath mats of *Carpobrotus rossii* or growths of partially dead but still flowering *Pelargonium australe*, 30-60 cm high. On Doughboy I., whether shelter is sufficient for its survival, the trailing stems of *Acaena anserinifolia* roof some of the nesting chambers. Less permanent mats of *Holcus lanatus* function similarly in a few instances but are not favoured by the birds.

EROSION FROM BIRD TRACKS AND TAKING-OFF POINTS

During the nightly landfall at dusk airborne mutton-birds usually come to earth close to their burrows and have but a few metres of land travel to undertake before reaching them. Taking off just before dawn presents rather more problems, difficulty being experienced in becoming airborne unless there is a high wind.

On the smaller or more steeply sloping rookeries, such as that of Granite I., birds flap clumsily over the rookery surface and have gained sufficient momentum before reaching the sea. On larger or flatter rookeries certain elevated taking-off points are selected, and tracks converge on these from surrounding parts of the rookery. Often the take-off points are bare granite outcrops. If they are soil-covered the vegetation soon becomes worn down to a sparse, trampled carpet of hemicryptophytic grasses and herbs or disappears altogether.

Where no suitable eminences present themselves tracks lead right to the shore, the birds half flying, half running down their length and occasionally becoming airborne before reaching the sea.

This type of track is always used by the flightless penguins, which must walk both ways. Although well able to land on rocks, penguins prefer the ease of sandy beach landings and, where beaches are scarce, minor tracks from different parts of the rookery converge like the tributaries of a stream to form a main highway as much as 2 metres wide leading to a suitable beach.

It is possible to distinguish between mutton-bird and penguin tracks by the fact that all footprints point downhill on the former; on the latter, half point uphill although a proportion of these would have been obliterated during the most recent morning exodus. In many instances both species use the same tracks. Towards the end of the fledgling season the footprints on the upper parts of the mutton-bird tracks become confused because the young birds wander round at exercise outside the burrows during the hours of darkness.

Another distinguishing character is the degree of fouling on the tracks. It takes mutton-birds little time to flap down to the sea at dawn. For incoming penguins

the track might be uphill all the way for a distance of several hundred metres. There are many pauses for breath, during which defaecation occurs.

The sandy soil is scuffed sideways and sent downhill, and the resulting depressions form natural run-offs for rain water, so that tracks may become scoured out deeply. They form an important erosion potential and are a particular hazard on the sandier soils.

The main track leading from the NE. rookery to the N. beach of Rabbit I. has started a long, narrow sand-blow, which is visible from the mainland several miles away as a yellow scar from summit to beach.

Tracks are most often bare of vegetation during the breeding season, but not infrequently show the dead remains of short-lived grasses and Caryophyllaceae plants (e.g. *Poa annua*, *Vulpia bromoides*, *Cerastium glomeratum*, *Polycarpon tetraphyllum*, *Sagina* spp., and *Stellaria* spp.), which colonize them during the undisturbed winter period. Loose mats of the prostrate woody stems of members of the Aizoaceae sometimes cross the tracks, denuded of leaves where trampled but still supporting growth in the distal portions.

On islands such as Benison, where the routes are used only by mutton-birds, the downward track may diffuse outwards at the top of a steep slope, and birds flapping down the slope comb the trailing vegetation in a downward direction but exert insufficient pressure to destroy it.

Little clusters of coprophiles are frequently centred round the penguins' defaecation points, which are often on level patches above particularly steep and exhausting stretches.

Effect of Rabbits on Rookery Vegetation

Rabbits were often introduced on offshore islands by seamen as a potential source of food that could be utilized when the mutton-birds are not in residence, and even islands visited as seldom as the smaller Glennies have their quota. Only a few rabbits on an island such as Citadel, where the vegetation is so severely depressed by exposure and lack of soil, can be of serious consequence.

In retarding plant growth and the resultant soil accumulation, the rabbits help to prevent the area from maturing into a potential rookery, and burrowing birds are relegated to such rock crevices as are available. On Citadel I. it is likely that the habitat is too far from the optimum for removal of the rabbits to have any great or immediate effect. In the slightly less adverse environment of Dannevig I., however, their presence probably has an appreciable effect in slowing down extension of the rookery and hastening loss of rookery area by contributing to soil erosion.

These rabbit populations can never become large, because of the limiting effect of the meagre food supply in summer. The ecosystem has reached a low point of equilibrium, at its lowest in a dry summer such as 1959, where the rabbits keep the plants in check and the plants keep the rabbits in check.

The succulent leaves of *Disphyma australe*, one of the chief species of these habitats, are eaten by rabbits in reasonably sheltered conditions, but the stunted, red-leaved forms of the more exposed habitats are very salty to the taste and are not relished on these usually waterless islands. On Citadel I. the comparatively rare ferns and grass (*Asplenium obtusatum*, an unidentified member of the Polypodiaceae, and *Danthonia caespitosa*) are most severely grazed, and survive as a relict population in narrow crevices, where the tips of the leaves are eaten off

almost as soon as they emerge. The much more abundant *Disphyma* is grazed, inevitably, but much of this grazing can be attributed to Cape Barren geese.

The most serious rabbit infestation is seen on Rabbit I. The estimated population there is small in relation to the total area, but large in relation to the amount of available food. The general impression is of an area which has been 'eaten out' and is carrying a residual rabbit population limited by the sparseness of food plants.

As not uncommonly with island populations in both hemispheres, the proportion of black rabbits is high; in fact all rabbits seen were black. All were feeding on the greener vegetation of the steeper cliffs and there were few dung pellets and fewer palatable plants in the rookery, which occupied the main part of the island. The wiry tussocks of *Poa poiformis* form the sole plant cover over most of the island during the summer breeding season and the locally associated plants of the sandier areas are as coarse and uninviting as the dominant. Those remaining in late summer are *Ammophila arenaria*, *Pteridium esculentum*, *Scirpus nodosus*, *Carduus tenuiflorus* and *Senecio lautus*, the two latter dead. In this rookery the soft, regenerating *Poa* shoots seemed to be the only source of food utilized. The leaves of a small patch of *Acacia longifolia* that persisted on the summit were seen to be eaten off as high as a rabbit could reach.

Most palatable species had retreated to the less accessible cliffs, where they formed a relict flora indicative of what the whole might have been in the absence of rabbits. 8 of the 10 species listed below as being found only in areas difficult of access are succulents, a group of plants favoured by herbivores, but of these *Bulbine semibarbata* and *Carpobrotus rossii* are normally grazed little if other food is available.

Relict flora of the less accessible cliffs:—

<i>Agrostis avenacea</i>	<i>Spergularia media</i>
<i>Bulbine semibarbata</i>	<i>Crassula sieberiana</i>
<i>Disphyma australe</i>	<i>Sambucus</i> sp.
<i>Carpobrotus rossii</i>	<i>Lobelia anceps</i>
<i>Calandrinia calypttrata</i>	<i>Cotula coronopifolia</i>

Soil depth is adequate for burrowing on Rabbit I., and destruction of so much of the plant cover by rabbits is not of serious consequence to the mutton-birds in a normal season. The year 1959 proved abnormal, however, and the detrimental effects of the heat wave on the birds was greatly accentuated by the paucity of shade resulting from the presence of rabbits.

In many cooler, moister areas of southern Tasmania and western Britain rabbits and shearwaters breed successfully side by side in the same warrens—even in different branches of the same burrows. There the effects of the rabbits are beneficial to the shearwaters rather than otherwise, in that they construct burrows often utilized later by the birds and eat down tall vegetation that is likely to choke the burrow mouths (Gillham 1955).

Since the depletion of the rabbits by myxomatosis and 1080 poison, a number of Tasmanian rabbit warrens have been taken over by expanding mainland populations of mutton-birds. There are, in fact, instances in the SE. of the State where the few surviving rabbits are reported to be ousted from the burrows by the returning birds in spring and forced to spend the summer lying up in the bracken, returning to the warrens in autumn when the birds go away to sea.

Effect of Heat Wave on Shearwaters in Two Types of Rookery

Many hundreds of shearwaters on Rabbit I. appeared to have succumbed to the exceptional heat wave of January 1959, when temperatures of as much as 110°F (43.3°C) were recorded on several consecutive days in Port Welshpool. Most of the victims were adult birds, but newly hatched chicks seemed not to have been affected, although the heat was still at its maximum when the island was visited on 18 January 1959 (108°F (41.1°C) at the lighthouse meteorological station on the SE. tip of Wilson's Promontory).

The dead birds lay, uninjured, in the mouths of their burrows or just outside. An oily, dark green splash on the ground beside most of them showed where the crop contents (studded with the black eyes of the small krill that formed the food) had been emptied prior to death.

As most of the burrows still contained eggs or newly hatched chicks, one of the adult birds was usually present. Had the heat wave fallen as little as a week later, when most of the birds were coming in only at night (Serventy 1958), they might have escaped unscathed.

The body-temperature of the adult short-tailed shearwater when incubating or brooding within the burrow is approximately 38°C (100.5°F), or 2-3°C lower than that of more active birds on the surface (Farner and Serventy 1959).

No facilities were available for measuring soil temperatures on Rabbit I., but Farner and Serventy, working in the Furneaux Group, Bass Strait, describe the burrow as providing a relatively stable micro-climate. They quote a diurnal temperature range in unoccupied burrows of 1.5°C (*c.* 2.9°F) as opposed to 15-30°C (*c.* 27-54°F) in the atmosphere, and a mean maximum burrow temperature during the period February-April inclusive of 20.5°C (69°F) in mid-February.

In western Britain it has been shown that, notwithstanding this mitigation of diurnal range as compared with that of the open air, the temperature and its fluctuations are much greater in and immediately adjacent to shearwater burrows than in soil of equivalent depth elsewhere (Gillham 1956a). Fluctuations of air temperatures within burrows are transmitted to the surrounding soil, and the time lag in loss of heat from the soil as compared with that from the air will serve to maintain high temperatures within the burrows well into the evening.

It is of interest in this matter that Specht and Rayson (1957) showed that in the warmer, drier conditions of SE. South Australia soil temperatures near the surface or unburrowed sands may be even higher than those of the atmosphere during the late afternoon in summer. Thus, when the air temperature had dropped to 29°C (84°F) at 4.30 p.m., the temperature at a depth of 3" was 36°C (97°F) and at 6" 30.5° (87°F). This 3" maximum was 2.5°C (4.5°F) higher than the maximum air temperature, which was attained some 2-3 hours earlier.

In January 1951 the maximum soil temperature at a depth of 6" in the South Australian soil was the same as the air temperature, and that at a depth of 3" was 10°C (18°F) higher (36°C and 46°C, or 97°F and 115°F, respectively). At a depth of 12" the temperature was only 6°C (11°F) lower than the air temperature (30°C or 86°F). Had shearwater burrows been present, it is likely that the high 3" temperatures would have extended further below ground towards the nesting chambers.

These readings were made in open sandy areas such as were common on Rabbit I., and the temperatures obtaining on Rabbit I. during the January 1959

heat wave are likely to have been closer to the South Australian temperatures than to those with which Farner and Serventy were working. Where the sand was shaded by vegetation, Specht and Rayson recorded differences of up to 4.1°C (7.4°F) at depths of 3" in summer.

Benison I. in Corner Inlet was visited 30 hours after leaving Rabbit I., when the heat wave was still in progress, but very few uninjured corpses or expectorated crop contents were seen there. Mauled carcasses were present—as a result of predation—but there had been insufficient time for any wholesale killing, such as had occurred on Rabbit I., to have been masked by carrion-feeders. As Benison I. is a less oceanic habitat than Rabbit I., it is likely that temperatures there had been as high if not higher during the previous week, but the rookery is of a different type.

Benison I. has relatively little of the bare ground that is so prevalent on Rabbit I. between the *Poa* tussocks, the sun's rays being deflected in the main rookery by close mats of *Carpobrotus rossii* and tall stands of *Pelargonium australe*, and in marginal parts of the rookery by tall *Lomandra longifolia*, *Pteridium esculentum*, *Melaleuca ericifolia*, etc. The succulent leaves of *Carpobrotus*, like those of *Disphyma australe*, *Crassula sieberiana*, and *Dichondra repens*, were severely wilted, and the loss of water by transpiration would in itself have served to lower the temperature near the soil surface.

The severity of the heat wave in Corner Inlet may be judged by its catastrophic effects on species of the intertidal zone. Widespread death occurred among the two barnacle species, *Chamaesipho columna* and *Tetraclita purpurascens*, and the false limpet, *Siphonaria tasmanica*, while *Hormosira banksii* and *Zostera muelleri* were blackened and withered (J. Thomson pers. com.).

Marine life was seen to have suffered similarly on islands in Port Phillip Bay on 16 January 1960 during a similar heat wave with temperatures over the century mark. The burrowing birds on these islands (Mud I. and S. Channel Fort I.), however, were storm petrels (*Pelagodroma marina*). This species ranges farther north than *Puffinus tenuirostris*, and no deaths from heat were seen among either adults or chicks.

The rookery vegetation on Granite I. has a shading capacity intermediate between those of Rabbit I. and Benison I., and on 27 January 1959, dead birds and expectorated crop contents were far fewer per unit area than those seen on Rabbit I. This was, however, almost a week after the worst of the heat wave had passed, and none of the corpses remained intact. As it is not possible to distinguish between damage by predators and that by scavengers, deaths could not be attributed with certainty to heat—it can only be stated that dead birds were more abundant than was usual in the probable absence of mammalian predators.

The sensitivity of *Puffinus tenuirostris* to high temperatures may be indicated by the restriction of nesting colonies to SE. Australia. D. L. Serventy (pers. com.) states that breeding success is lower than average, for no apparent cause, in the most northerly part of the breeding range near Ceduna in South Australia, and it seems in the light of Victorian evidence that high temperatures may have some bearing on the matter; exceptional heat spelling a 'bad year' there, just as exceptional rain with its attendant flooding of burrows signifies a 'bad year' in Tasmania and Bass Strait rookeries. For every breeding adult killed there is a high likelihood that the dependent chick will also die.

Maintenance of a reasonable vegetative cover in the rookeries during the heat

of the summer would thus appear to be most essential to *Puffinus tenuirostris* in regions where it is most difficult to achieve, viz., the marginal parts of the nesting habitat in South Australia and New South Wales.

Grazing in rookeries in the drier areas by farm livestock should be avoided where possible and, if carried out, should be limited to the winter and discontinued in time to give the plants a chance to regenerate before the return of the birds in spring.

Predation by Foxes, Feral Cats and Others

One of the most important predators of the mutton-bird, but fortunately a localized one, is the fox, which can create havoc in a small rookery in the course of a few nights. Of the 9 islands considered in this paper only Benison I. has a population of foxes, but foxes take a large toll of mutton-birds in more westerly parts of Victoria (e.g. Phillip I. in Western Port Bay, Griffith I. off Port Fairy, and Cape Grant near Portland).

Foxes reach Benison I. from Wilson's Promontory across the mud flats at low tide. The sandy beaches of the island were seen to be liberally imprinted with their tracks, while their dung was scattered throughout the rookery. Hundreds of dead mutton-birds lay around the island, some merely nipped at the back of the neck and left, others more extensively damaged—possibly by carrion-feeders subsequent to the initial attack. These were especially abundant at the open taking-off points, where the birds converged at dawn and where they would fall an easy prey to a waiting fox.

Carcases were not restricted to the rookery, many having been dragged into the cover of the scrub, some even into the lower branches of *Banksia integrifolia* trees. (It is conceivable that some of the latter had been eaten by scavengers after getting caught in the branches—a not uncommon fate of the shearwaters and petrels nesting in scrub—but all were in locations readily accessible to foxes.)

The cover afforded to foxes and/or feral cats by scrub might be a factor contributing towards the scarcity of occupied burrows in the denser cover.

Feral cats, offspring of domestic cats abandoned by former lighthouse-keepers, have worked havoc among the mutton-birds of Gabo I. A formerly large population there had been reduced by 1959 to little more than 100 pairs surviving in small groups on the E. and W. coasts.

A large number of abandoned burrows were present in the E. coast rookery, wholly or partially overgrown by lush *Carpobrotus rossii*, and only about 40 burrows showed signs of recent occupation. Within this small rookery 30 dead mutton-birds were counted—a sufficiently high proportion of the total population to suggest that the colony was doomed to extinction during the next few years unless the cats were destroyed. 14 of the corpses had been dragged to an unburrowed peaty hollow about 6 sq. metres in extent on the island side of the rookery and were not on the birds' route to the sea, as were the aggregations of fox leavings.

(Extensive damage by feral cats occurs also in the Tasman I. rookery off SE. Tasmania, but this colony is still sufficiently strong to withstand fairly severe predation.)

Lighthouse-keepers on Cliffy I. reported that birds were more numerous in the small rookery there in 1959 than they had been in the few previous years, when a domestic cat and a dog had been preying on them. The colony still totalled fewer than 100, most individuals nesting in inadequate burrows or beneath grass tus-

socks, which afforded little protection from predators. Birds were more numerous on the adjacent uninhabited Rag I. and Seal I., where they were untroubled by domestic pets. The lighthouse-keepers had no knowledge of fairy prions, which had previously nested on the island but were not found in 1959, and these may have been exterminated.

Predation by man is difficult to assess, but undoubtedly occurs on many of the islands, particularly the inshore ones. Rabbit I. is reported by the local Fisheries and Wildlife Inspector (J. Rhodes) to be a popular, though illegal, harvesting area for local holders of Tasmanian birding licences who fail to get as far as the Furneaux Group!

Mutton-birds are no longer found on Deal I. in the Kent Group further S., where carcasses excavated by lighthouse-keeper C. Garreau from old rookeries have been identified as those of *Puffinus tenuirostris*, and this is believed to be an area where extermination has been effected by man.

There was no evidence of snake predation, although both black tiger snakes and copper-head snakes have been seen taking birds in other areas.

Nowhere were avian predators particularly numerous, and it is likely that the Pacific gull is the most important.

The raven (*Corvus coronoides*) was unusually abundant around Rabbit I. and the Corner Inlet islands in late January, having possibly been attracted by the large amount of carrion in the form of dead mutton-birds.

Other unusually abundant creatures on these inshore islands were the harlequin bug (*Dindymus versicolor*), which frequented the *Lavatera plebeja* with *Acanthucis trispinifer*, and a small brown bug belonging to the family Lygaeidae. The former, although a plant sucker, can be attracted experimentally by carrion (J. Thomson pers. com.); the latter is often associated with areas fouled by various types of seabirds elsewhere.

Colonies of Burrowing Birds Other Than the Short-tailed Shearwater

PETREL COLONIES

All islands except Citadel I. possess colonies of short-tailed shearwaters (*Puffinus tenuirostris*), and the foregoing observations apply to rookeries of this species. Most apply equally well to the rookeries of other burrow-dwelling birds.

Small petrel burrows were found on only two of the Glennie Group—several hundred on Dannevig I. and possibly rather more on McHugh I. It is suspected that these belonged to diving petrels (*Pelacanoides urinatrix*) as dead birds of that species were seen on both islands, and a specimen from McHugh I. was identified by Dr D. L. Serventy. This appears to be the first record of that species for the Glennies.

On Dannevig, as on 8 white-faced storm petrel (*Pelagodroma marina*) islands visited in the Furneaux Group, the dominant *Poa poiformis* adopted a short, dense growth habit around the petrel burrows, forming a thick mat very different from the taller isolated tussocks of a shearwater rookery. On McHugh I. the burrows were mixed with those of shearwaters and penguins and the vegetation was of 'normal' rookery type.

A small number of fairy prions or dove petrels (*Pachyptila turtur*) were reported by the Victorian Bird Observers' Club to nest on Clifty I., but burrows of these were not seen.

PENGUIN COLONIES

On 5 of the islands (Dannevig, McHugh, Cliffy, Rabbit, and Gabo) penguins (*Eudyptula minor*) and mutton-birds share the same territory, but penguins seem on the whole to have a slightly more oceanic distribution than mutton-birds. Penguins are present on Citadel I., where mutton-birds apparently do not occur because of the unsuitability of the severely exposed habitat, and are absent from the 3 sheltered Corner Inlet islands, where mutton-birds are abundant.

This type of distribution pattern is paralleled on Phillip I. farther W., where mutton-birds extend approximately $2\frac{1}{2}$ m. farther up the W. coast into the more sheltered waters of Western Port Bay than do penguins.

Rookery vegetation is essentially similar with the two species, but the more drastic fouling outside penguin burrows when the young birds are present leads to greater destruction of indigenous vegetation and stimulation of transitory growths of coprophilous aliens.

Where many thousands of penguins burrow in the Gabo I. sand, the more usual arenicolous vegetation of tussocky, rhizomatous monocotyledons or dune shrubs has yielded place to the succulent and markedly coprophilous *Carpobrotus rossii*, a common plant in the more densely populated rookeries around Tasmania, and also in others less densely populated but where blown sea salt increases the high concentration of soil salts brought about by guano. In the N. of Gabo the *Carpobrotus* extends from coast to coast and farther S. it marks the occurrence of inland pockets of penguins in other vegetation.

Towards later summer much of the excess guano is washed away, but the burrows are still distinguishable by the accumulations of feathers from moulting birds. The burrows are frequently shorter and broader than the average mutton-bird burrow and sometimes are located in resistant substrata that might have proved untenable to mutton-birds.

Nesting Colonies of Silver Gulls

Silver gulls (*Larus novae-hollandiae*) nest on Cliffy I., Rabbit Rock and Granite I.

On Cliffy I., where about 100 pairs occurred on the N. slopes in the early summer of 1959, the nests were sufficiently diffuse for the vegetation to have been stimulated rather than otherwise by their presence. The dominant *Disphyma australe* (which is much the most characteristic species in colonies of surface-nesting seabirds in N. New Zealand (Gillham 1960b)) is generally dominant over the island as a whole, but it grew more vigorously in the gull colony. Production of anthocyanin was inhibited and the unusually green shoots grew erect at the tips to give a dense, moisture-retaining carpet 30 cm deep. The lush growth had obliterated most of the nests by 19 March 1959, and occupied 98% of the area, excluding granite outcrops. The only other species were *Calandrinia calyptata*, *Lobelia anceps*, *Salicornia australis* and *Sonchus oleraceus*.

On Rabbit Rock the gullery was co-dominated by *Disphyma australe* and *Poa poiformis*. Crested terns (*Sterna bergii*) were present there.

It was estimated that rather more than 100 pairs of silver gulls nested on the lower S. slopes of Granite I. The guano-resistant *Disphyma* does not occur on this less oceanic island and the indigenous flora was severely depressed, although nests were widely spaced, usually several metres apart. The original sandy soil derived

from the parent granite had become metamorphosed into an organic-rich clay impregnated with guano to a depth of 5-10 cm. As in the Gabo penguin colony, in the absence of *Disphyma* the closely related *Carpobrotus rossii* was dominant, but *Lepidium foliosum*, another ornithocoprophilous species, showed a marked local increase. Other species were *Bulbine semibarbata*, *Lavatera plebeja*, *Pelargonium australe*, *Poa poiformis*, and *Sonchus oleraceus*.

The following percentage frequencies of plants actually touching nests indicate that *Lepidium*, although not dominant in the area as a whole, might be more guano-resistant than the dominant *Carpobrotus*, and it is certainly a 'bird indicator' on the Bass Strait islands: *Lepidium* 65%, *Carpobrotus*, 35%, *Poa* 15%, *Sonchus* 5%.

The green leaves of a live *Poa* tussock had been bent over and woven together to form the fabric of one nest.

Food remains at the end of January, when some of the nests still contained eggs and young chicks, suggested that the crustacean *Squilla mantis* figured largely in the birds' diet at that season.

Cormorant Roosts

No nesting colonies of cormorants were seen, but areas frequented by both ground-nesting and tree-roosting species were examined.

Well over 100 black-faced or white-breasted cormorants (*Phalacrocorax fuscescens*) roosted on the N. end of Granite I. and their guano, which extended half-way to the summit, was visible from a distance of several miles. The most frequented rocks close to sea level bore thick deposits of guano and no vegetation. At the margin of this area tall, partially dead *Lepidium foliosum* was conspicuously dominant, and other more generally distributed species had been almost killed out.

Fig. 2 shows the histogram of a 6-yds-wide belt transect running from the lower limit of vegetation through the cormorant roost to the mutton-bird colony of the island summit.

Some depauperate *Poa poiformis*, the island dominant, survived in the roost, but most had been killed and the tussocks worn down to ground level by the trampling birds. Most of the small amount of *Carpobrotus rossii* had suffered a similar fate, and the other species present were the coprophilous *Senecio lautus*, *Lavatera plebeja*, and *Bromus diandrus*.

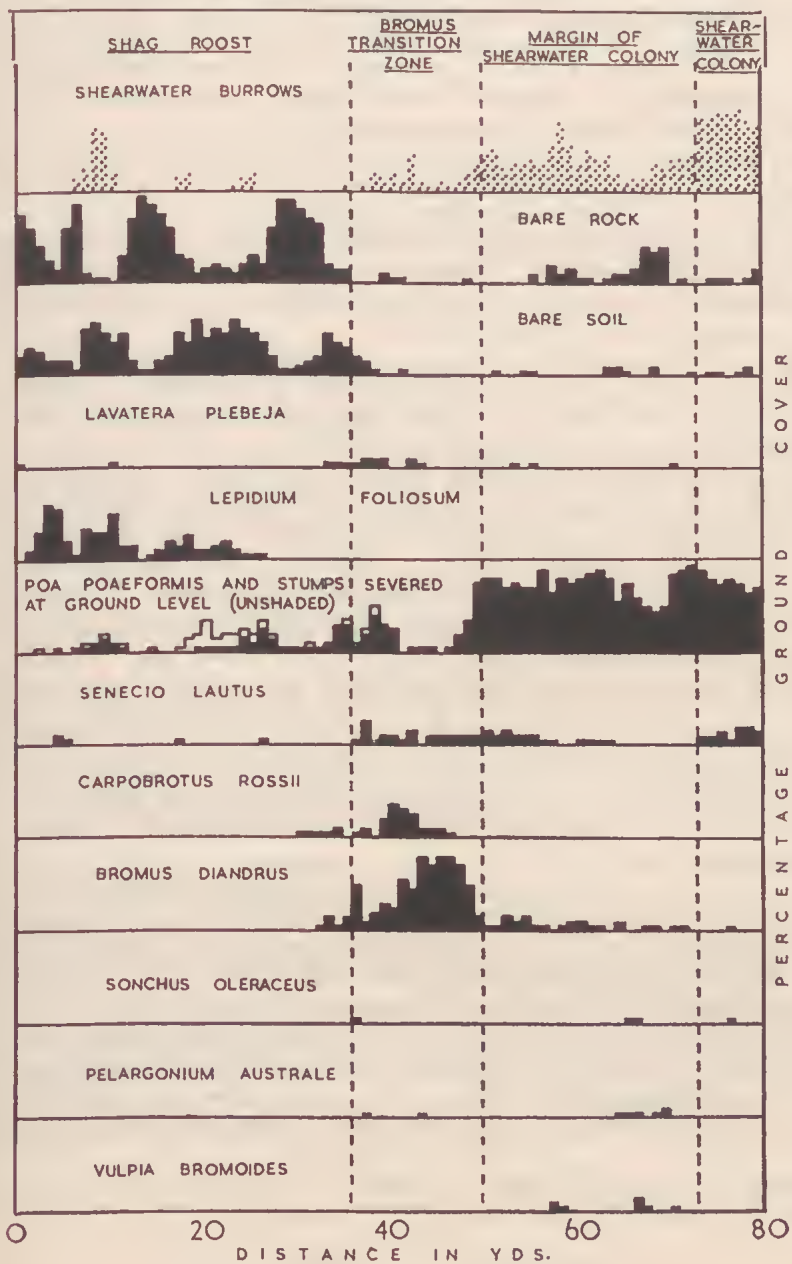
The last, although rare elsewhere on the island, became locally dominant in the transition zone between the *Lepidium* of the shag roost and the *Poa* of the shear-water rookery. Growth had formerly been very lush, but the plants were now dead and many of them trampled flat. This annual grass was a common winter invader of areas bared by birds in some of the Phillip I. rookeries.

Lepidium did not occur in the transect in the transition or mutton-bird zones, but the other, less markedly coprophilous species became progressively more abundant with increasing distance from the cormorants.

Mutton-bird burrows occurred in the guano-impregnated soil of the cormorant roost wherever it was sufficiently deep, but much of the area was rocky and the average burrow density in the *Lepidium* zone was only 0.3 burrows per sq. yd. In the *Bromus* transition zone it rose to 0.5 burrows per sq. yd., in the marginal *Poa* zone to 1.2 per sq. yd., and in the rookery proper to 2.7 per sq. yd.

The characteristically ornithocoprophilous green alga *Prasiola* was common on rocks in the transect area. Specimens from Granite I. (and from gull and cor-

Fig. 2—Granite I., Corner Inlet, 27 January 1959. Transect up NE. slope from 5 yds above HWM through shag roost to shearwater colony; 80 x 6 yds.



morant colonies in N. Tasmania) were determined by Dr H. B. S. Womersley as probably *P. stipitata*—these constituting only the second record for Australia. The previous specimens were collected by C. Beaglehole on the Lawrence Rock ganetry off Portland, W. Victoria, and it seems fairly certain that the genus is widespread on the bird islands of SE. Australia—as it is on bird islands of New Zealand (principally *P. stipitata*), Great Britain (principally *P. crispa*), and Macquarie I. (principally *P. crispa* ssp. *antarctica*).

The Cyanophyceae, members of which algal group are commonly present in guano-fouled rock pools near high-water mark in Britain, was here represented by a brown seum of *Lyngbya* sp. (Det. L. Osborne).

Black-faced and large black cormorants (*Phalacrocorax carbo*) roosted on rocks on the NE. side of Doughboy I. Again the heaviest fouling was on granite slabs below angiospermous vegetation, but it was sufficiently potent higher up to cause conspicuous modification of the vegetation.

The generally dominant *Pteridium esculentum* and *Correa alba* of the slopes above gave way to a transition zone of *Acaena anscrinifolia*, *Sonchus asper* and *Vulpia bromoides*, and these, in turn, to pockets of highly guano-resistant species in the guano-saturated soil between rock outcrops.

The species suffering the greatest guano-deposition, and often with the entire photosynthetic surface coated with a hard layer of white excreta, were *Chenopodium glaucum* and *Poa annua*, the latter partially dead and a relict of an earlier, moister phase. Other ornithocrophilous plants showing a local increase were *Carduus tenuiflorus* and *Urtica incisa*. Almost 50% of the 27 species in the upper part of the cormorant roost were aliens, some (e.g. *Euphorbia peplus* and *Leontodon hirtus* = *L. nudicaulis*) being seen only there; others (e.g. *Poa annua*) being associated also with mutton-birds but not being seen outside the rookeries.

Large black cormorants roosted in spindly, 3-metre-high *Melaleuca ericifolia* trees on the SE. of Doughboy Is. Some the trees had been completely killed, some partially killed, and all had thick coatings of guano adhering to the higher horizontal branches. Many of the smaller branches had been exfoliated or snapped off by the cormorants (cf. damage to trees in New Zealand cormorant colonies, Gillham 1961b).

Excreta lay $\frac{1}{2}$ -1 cm thick on the peaty soil beneath the trees and were sufficient to have caused a local change in the ground vegetation. As in the ground roost, the dominant bracken gave way to other species, only a few sickly fronds surviving, although this roost was on the inland side of the scrub patch. The 3 species that shared dominance in its stead were *Senecio minimus*, *Solanum aviculare*, and *Vinca major*. The *Senecio* was dead, as in the mutton-bird rookeries at the same season; the other 2 were green and thriving although heavily splashed with guano. Spindly, nitrogen-stimulated *Conchus oleraceus* showed a local increase where excreta was abundant. Mutton-birds burrowed in partially bare soil beneath these trees.

Kershaw et al. (1913) made no mention of cormorants being present when they visited the island in December 1912.

Grazing by Cape Barren Geese

Signs of Cape Barren geese were seen only on the 3 islands of the Glennie Group, and the largest flock was of only 15 birds on Dannevig I. As in the Furneaux Group, where flocks of several hundreds frequent some of the outer islands,

their dung pellets were particularly abundant on granite outcrops that commanded wide views of the surrounding terrain.

No nests were found when the islands were visited in March, but the nests would have had ample time to disintegrate since they were vacated by the young birds several months previously and they were seldom seen at that season on islands where they were known to exist.

Large areas of *Disphyma australe* had been grazed—only the distal parts of the leaves being taken—and the swards were severely fouled in parts. Some of the less xeromorphic, broad-leaved *Poa poiiformis* of crevices had been eaten, and fibrous remains in the dung suggested that this type of food, possibly collected over a wide feeding range, might figure more largely in the diet than was apparent from observation of the local vegetation. It was possible, however, that the succulent *Disphyma* leaf tips would leave few identifiable remains after passage through the alimentary canal, so that dung analyses would not prove to be a measure of species preferences.

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THE RIVER DELTAS OF THE GIPPSLAND LAKES

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Abstract

Deltaic sedimentation at the mouths of rivers flowing into the Gippsland Lakes has been influenced by the silt-trapping effects of lake-shore reed growth (chiefly *Phragmites*). The reed-fringed deltas of the Latrobe and Avon in L. Wellington continue to grow but the deltas of the Mitchell, Nicholson and Tambo in L. King are being consumed by wave erosion, following the disappearance of a former shoreline reed fringe indicated by die-back features and by historical and cartographic records. Loss of *Phragmites* is correlated with increased salinity in L. King.

Hypotheses advanced for the origin of the Mitchell 'silt jetties' are discussed in the light of evidence from the valley floor S. of Bairnsdale, where a former lake-shore beach is identified. It is concluded that this delta grew from the vicinity of Bairnsdale southwards to Eagle Point Bluff and thence eastwards into L. King.

Introduction

The Gippsland Lakes are a group of coastal lakes in E. Victoria, between 150 and 200 m. E. of Melbourne. They developed during Recent times, when the world-wide marine transgression that accompanied the reduction of the Pleistocene ice sheets submerged the lower parts of the E. Gippsland river valleys to form a broad embayment. This was subsequently cut off from the sea by the formation of a series of sandy coastal barriers bordered on the seaward side by the Ninety Mile Beach. The lakes thus enclosed include L. Wellington, L. Victoria, L. King and a number of smaller lagoons, and are fed by 5 main rivers, the Latrobe, Avon, Mitchell, Nicholson and Tambo. At Lakes Entrance they open to the sea by way of an artificial outlet cut through the coastal barriers in 1889.

These lakes have had a very complex physiographic history. Their configuration has changed as the result of erosion and deposition by waves and currents, by the encroachment of swamp land around their shores, and by the growth of deltas at the mouths of the inflowing rivers. These changes continue, and it is clear that, in terms of the geological time-scale, the Gippsland Lakes will not exist much longer; sedimentation will convert them into a depositional coastal plain, or marine erosion will destroy all trace of them.

The river deltas that protrude into the lakes are of considerable interest, and any attempt to describe their mode of origin must also account for their condition at the present time. The Latrobe and Avon are building deltas into L. Wellington, but the deltas built by the Mitchell, Nicholson and Tambo rivers in the N. part of L. King are being destroyed by wave erosion and it appears that the conditions which permitted their growth no longer exist. An enquiry into their mode of origin is best preceded by an account of the typical sequence of physiographic evolution in a submerged river valley.

When the lower reaches of a river valley are drowned by coastal submergence, river sediment is deposited in such a way that the drowned reaches become shal-

lower, until eventually an alluvial valley-floor is developed across them. Rivers with a seasonal regime, subject to flooding at certain times, tend to build natural levees, high banks of silt bordering the river channel. The best known are those along the lower Mississippi R. (Russell 1936), which are built up by deposition from flood waters. When a river rises and overflows its banks, inundating the valley

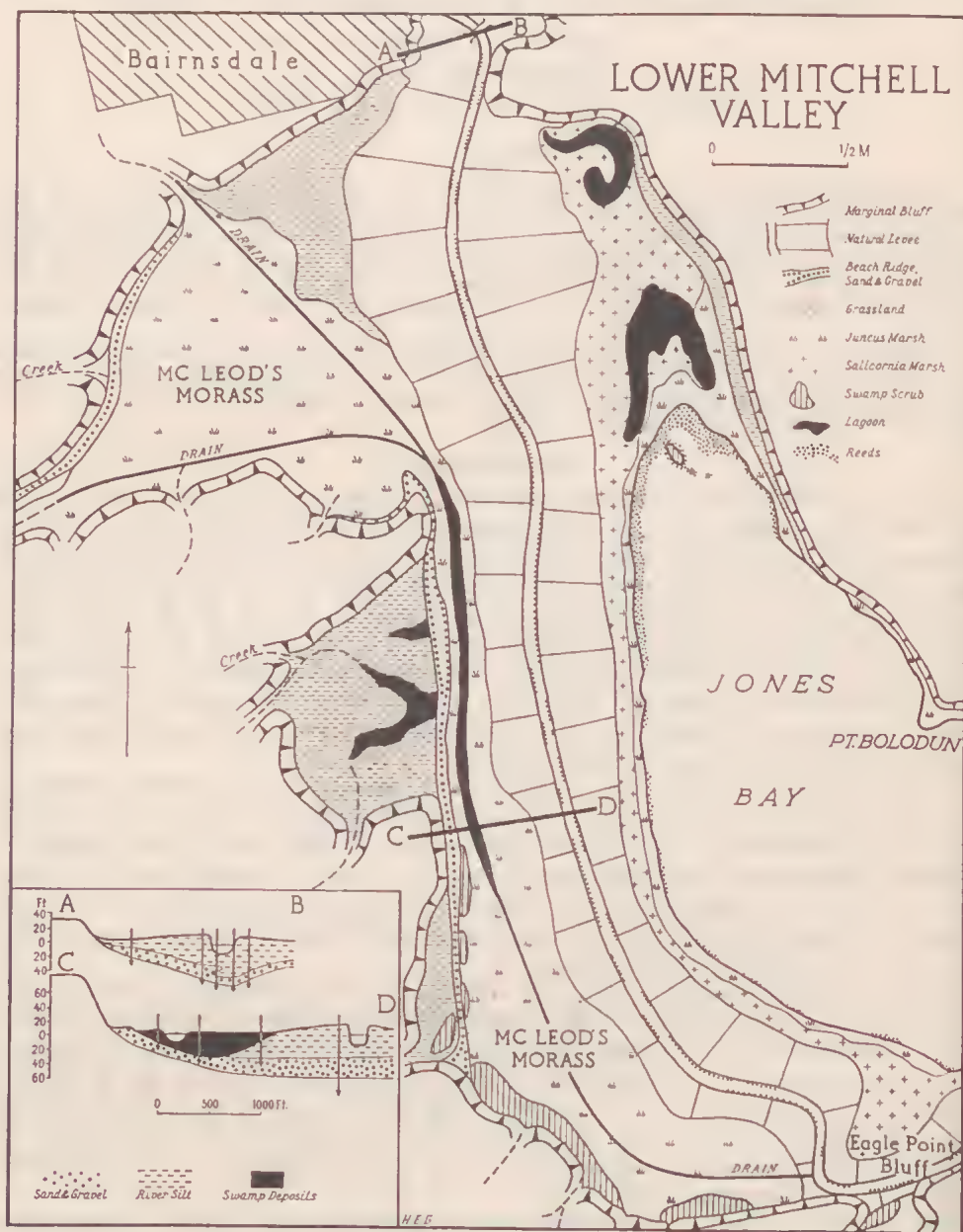


Fig. 1—The Lower Mitchell valley between Bairnsdale and Eagle Point Bluff.

floor, the flow of water is most rapid along the line of the river channel and much slower on either side. Silt carried by the floodwaters is relinquished at the borders of the channel, where the water velocity diminishes, and only the finer clay sediment is carried into the calmer water beyond. In this way a valley-floor that is being built up, or aggraded, by deposition shows a river channel bordered by natural levees which slope away into lateral depressions. In Louisiana these are known as levee-flank or backswamp depressions. Flood water may persist in them for long periods, particularly if the levees reach the valley side locally, so as to enclose depressions and prevent down-valley drainage. They are flooded with clay deposited from flood waters, and very often they are occupied by fen or swamp vegetation, which may build up peat deposits.

The process of deposition which produces natural levees can also take place at the river mouth, building jetties of silt that protrude into open water. In the Mississippi delta distributary channels have prolonged their natural levees as silt jetties, extending into the lagoons which are a feature of this subsiding delta. The Mississippi carries an enormous load of sediment, and is able to build a delta projecting into the Gulf of Mexico in spite of the counteracting effects of marine waves and currents and the continuing subsidence of the land.

The relatively small rivers that drain into the Gippsland Lakes show similar features. The lower part of the Mitchell valley (Fig. 1) shows well-marked natural levees bordering the river channel. On the W. side these slope down into McLeod's Morass, a typical lateral depression, but on the E. side the valley floor opens on to Jones Bay, an arm of L. King. Under natural conditions McLeod's Morass was very often flooded by water overflowing from the river or carried in by tributary creeks, and although an outlet drain has been cut the area is still very wet in winter. Much of it is occupied by giant rush (*Juncus pallidus*) swamp vegetation. Below Eagle Point Bluff, a cliff of Tertiary sandstone and gravel, the river swings eastwards into L. King, the natural levees passing into silt jetties that protrude far out into the lake (Pl. VIII, fig. 1).

The Mitchell has a marked seasonal regime with a maximum in late winter (Table 1), and is subject to severe flooding after heavy rain. Flooding occurs frequently in the E. Gippsland valleys in the winter months, and in spring when rainfall is augmented by snow melt from the Eastern Highlands (Table 2). The construction of well-marked natural levees and of deltaic silt jetties is certainly assisted by repeated inundation of the valleys with silt-laden flood waters.

TABLE 1

River flow in the Mitchell at Bairnsdale—mean values 1890-1921 in '000 acre-feet
(State Rivers & Water Supply Commission River Gaugings)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean Total
29	18	19	19	33	79	89	102	127	96	43	31	685

TABLE 2

Flood-incidence in E. Gippsland, 1911-53
(East Gippsland Resources Survey, 1954)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
4	5	1	6	6	10	15	10	8	11	3	4	83

The extent to which the present valley floors occupy sites that were submerged by the Postglacial transgression is not easily determined. A few years ago the Country Roads Board made a series of borings across the valley floor of the Mitchell at Bairnsdale in search of suitable foundations for bridge construction, and their borings (Fig. 1, A-B) passed through river silt into underlying sand and gravel deposits which may well have accumulated at the head of a submerged gulf. Relics of a former lake-shore beach at the W. margin of the valley floor below Bairnsdale will be discussed more fully later. It appears that, at the maximum extent of submergence, L. King reached as far as Bairnsdale and that the lower part of the Mitchell valley floor has been formed by subsequent deposition. Supporting evidence comes from the pattern of river meanders, which are close and intricate above Bairnsdale but open, sweeping curves in the lower course. The same transition is seen in the Latrobe below Longford, the Thomson below Sale, the Avon below Redbank and the Tambo below Swan Reach, and in each case it is likely that the more gradual meanders mark the section of the valley floor formed by deposition in an area that was once submerged, while intricate meandering signifies subaerial conditions uninterrupted by submergence. The author has observed similar features elsewhere, notably in the rivers of Sussex (England), where intricate meanders give place downstream to open meanders at the point where the graded profile of stream erosion disappears beneath almost flat alluvial flood plains in sections that were submerged by the Postglacial transgression. The deltaic sections of the E. Gippsland valley floors are thus more extensive than the deltas which actually protrude from the present lake shores, and the lateral depressions are essentially infilled arms of the lake adjacent to silt jetties that were first prolonged, then built up as natural levees by deposition. It is remarkable that these relatively small rivers have been able to build deltas that protrude into the lakes, and the circumstances in which they have done so require careful analysis.

The Latrobe Delta

The Latrobe delta (Fig. 2) is a cusate delta at the SW. corner of L. Wellington, built into a part of the lake that is sheltered from the prevailing westerly winds, but open to the easterly winds that frequently occur. Low natural levees bordering the river culminate in silt jetties that protrude into the lake, and the delta is covered by dense swamp scrub vegetation, mainly swamp paper-bark (*Melaleuca ericifolia*), with a few red gums (*Eucalyptus tereticornis*) on the river banks. Extensive reed fen, dominated by the common reed (*Phragmites communis*) and need mace (*Typha angustifolia*), occupies the lateral depressions bordering the Latrobe levees below Sale, which are frequently flooded. At the mouth of the river and along adjacent parts of the shore of L. Wellington there is a reed fringe dominated by the common reed, which is spreading outwards into the lake (Pl. IX, fig. 2). River silt is trapped by the reeds and built on to the delta, which is growing by prolongation of the jetties at its mouth and by marginal accretion along the lake shore. The reeds extend into water about 4 ft deep, but at their inner margin sedimentation has built up the land to a level at, or slightly above, average lake level, and here the reeds give place to swamp scrub dominated by *Melaleuca ericifolia*. The scrub is actually invading the back of the reed fringe, and as it takes over its shallow interlacing root network binds the soft lacustrine sediments. On the surface a mass of twigs, leaves and decaying bark forms brushwood peat, but just underneath this is silty material containing fragments of *Phragmites* straw, a relic

of the reed community now replaced by scrub. A foot or so below this there is often a very soft wet blue or black organic material, so weak that the surface raft of brushwood peat and scrub will often quake under the weight of a man. This vegetation zonation on the delta indicates an ecological succession that brings about the encroachment of swamp land along the lake shore. It is comparable with the encroachment succession from reed fen to alder-sallow carr, the swamp woodland that develops around the Norfolk Broads, in eastern England.

The Avon Delta

This is very similar to the Latrobe delta, but rather smaller. The Avon, joined in its lower reaches by the Perry, flows into the NW. corner of L. Wellington

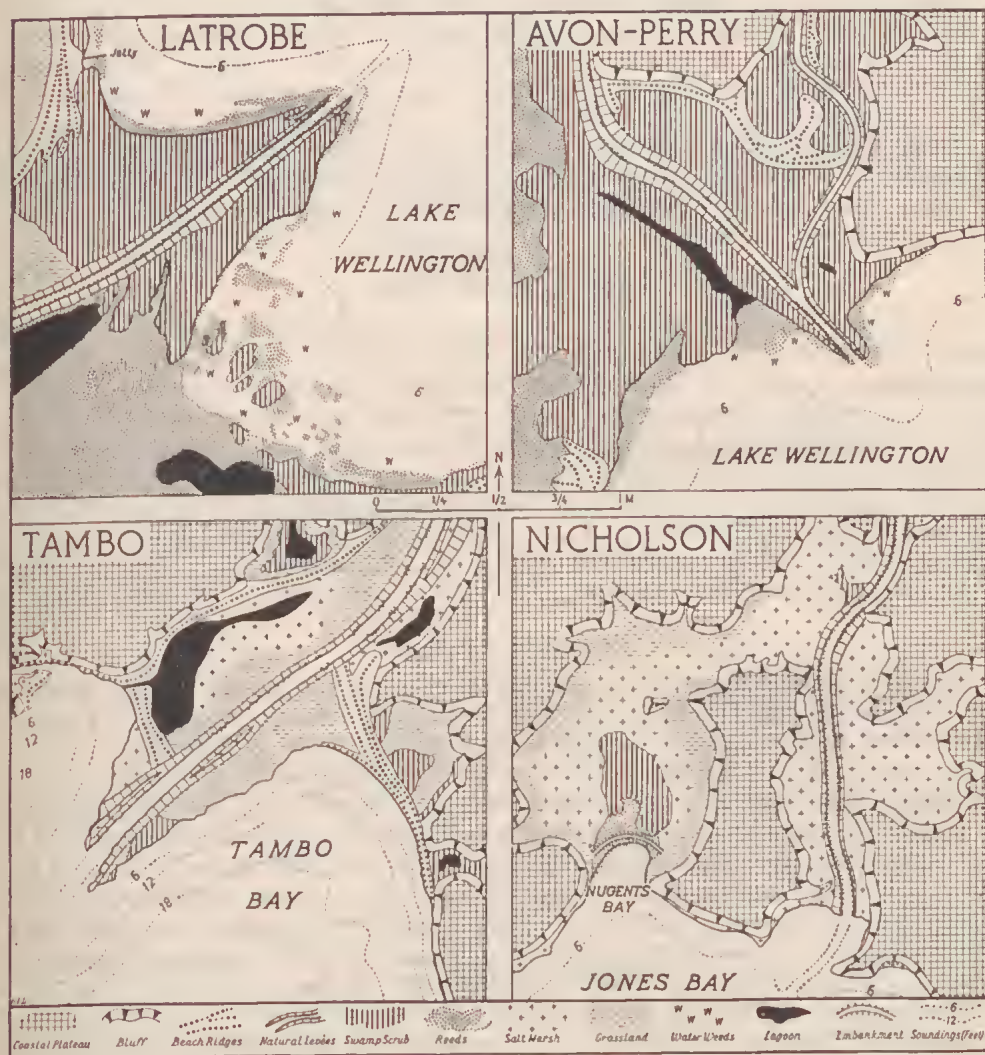


Fig. 2—The physiography and vegetation of the deltas of the Latrobe, Avon-Perry, Tambo and Nicholson R.

by way of a cusped delta. Reeds border the delta, and the succession to swampy scrub brings about encroachment at the mouth of the river and along the adjacent lake shores. At an early stage in the growth of this delta a sandspit was enclosed, and this can still be traced in the swamp land at the mouth of the Perry valley. *Phragmites* fen occupies the lateral depressions farther upstream.

The Tambo Delta

The Tambo delta in the NE. corner of L. King is similar in form to the Latrobe delta. A cusped delta has been built into the lake, outflanking and enclosing beach ridges. The natural levees which border the river slope away into lateral depressions occupied by shallow lagoons which dry out in summer, and by salt marshes; the *Phragmites* fen is not present here, or along the lake shore, but a sparse reed growth borders the river channel farther upstream. In the absence of a shoreline reed fringe there is severe wave-erosion of the delta margins. Their outline has become irregular, and a line of dead red gums standing in the lake mark their former extent (Pl. IX, fig. 1). The W. jetty has been cut back farther than the E., being more exposed to waves generated by the prevailing westerly winds. Swamp scrub probably covered this delta under natural conditions, but most of it has been cleared and converted to pastureland, and it is reclaimed pastureland which is suffering erosion.

The Nicholson Delta

The Nicholson, the smallest of the 5 main rivers that flow into the Gippsland Lakes, has not built a delta comparable with the others. At one time the river probably flowed out into Nugents Bay, but during the later stages of the Post-glacial submergence it breached a narrow interfluvium and flowed out into an arm of the lake formed by the drowning of an adjacent valley system. Salt marshes and *Melaleuca ericifolia* swamp scrub land now occupy these former embayments. *Phragmites* grows on an artificial bank built along the shore of L. King at Nugents Bay, and also on the river banks, but it is not present on the lake shore or around the river mouth. Wave erosion has cut out an embayment here, but the underwater topography suggests that a delta formerly protruded into the lake (Fig. 2).

The Mitchell Delta

The long digitate delta that winds into the N. part of L. King consists of silt jetties bordering the Mitchell R. (Pl. VIII, fig. 1). Its vegetation cover at the present time consists largely of pastureland, with patches of *Melaleuca ericifolia* swamp scrub and salt marsh, and *Phragmites* is confined to the E. end, except for a sparse growth along the river channel and at two or three places on the N. shore. Wave erosion is cutting back the margins of this delta (Pl. VIII, fig. 2), and salt marsh plants are invading pastureland on sites that are frequently splashed or sprayed by water from the lake. In 1919 a breach was made by the river just below Eagle Point during a severe flood (The Cut, Fig. 3), and more recently wave erosion has dissected the E. part of the delta into small islands. If present trends continue the Mitchell delta will wither and vanish during the next few decades.

The problem of the origin of these remarkable silt jetties has prompted several hypotheses. When the surveyors A. J. Skene and R. B. Smyth voyaged through the Gippsland Lakes in 1874, they saw the delta and suggested that it had grown from the vicinity of Bairnsdale southwards to the bluff at Eagle Point and thence

eastwards into L. King. In this way the Mitchell had achieved the reclamation of a considerable portion of L. King (Skene and Smyth 1874). A few years later, the geologist A. W. Howitt published an account of the area in which he described the silt jetties as well-timbered, reed-fringed features, and interpreted them as a tongue of lacustrine sediment along which the Mitchell had maintained a channel by means of the 'ploughing action of floods' (Howitt 1879). The mechanism is obscure, and the jetties are almost certainly constructional forms prolonged by

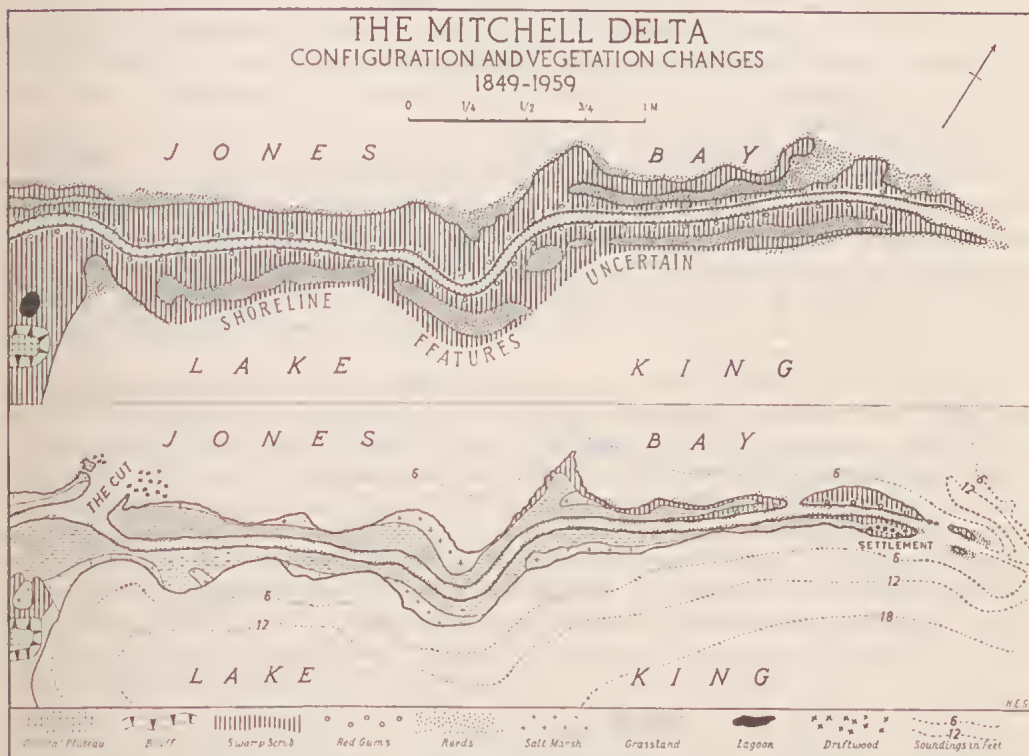


Fig. 3—The Mitchell delta as it was in 1849 (above) and as it was in 1959 (below).

deposition of silt at an advancing river mouth. J. W. Gregory (1903) took this view, pointing to the shoals, snags (dead trees and driftwood washed downstream) and patches of reeds beyond the river mouth as evidence of the future line of growth. At this time the delta had almost reached the farther shore of L. King and there was speculation as to whether it would impinge on that shore and deflect southwards or whether the outflow from Jones Bay, fed by the Nicholson R. would deflect it southwards before it reached the farther shore. This was never settled, for in the early years of the present century growth came to an end and in the last 40 years there has been considerable erosion.

Another hypothesis, put forward by H. T. Clifford (1949), was that the N. part of L. King was a submerged valley plain, and that the natural levees of the Mitchell remained partly exposed above sea level as silt jetties. When the valley

below Bairnsdale is flooded the river-bed levees look much like silt jetties protruding into the lake, but the difficulty with this hypothesis is the existence of a former lake-shore beach in the W. side of McLeod's Morass. This is a bank of sand and shingle at the foot of the valley-side bluff, extending as a barrier across the mouths of tributary valleys and protruding into the swamps at the N. end as a spit (Fig. 1). It consists of material that is very similar to the sand and shingle beaches found around the shores of L. King and L. Victoria and different from the silt which forms the natural levees of the Mitchell which stand between it and the present lake shore. At one stage, therefore, the lake extended to the bluffs on the W. side of the lower Mitchell valley. The Mitchell delta must have grown southwards from Bairnsdale across an embayment, much in the way that Skene and Smyth suggested, so that the silt jetties cannot have originated in the way described by Clifford.

It is remarkable that the silt jetties have grown so far without the breaching (crevassing) and branching that takes place along the jetties built by Mississippi distributaries, and it is clear that reed vegetation played a vital part in their evolution, the pattern of the reed community spreading into the lake each year and outlining the area in which sediment brought downstream during floods was trapped and consolidated. At present, in the absence of a reed fringe, the delta is being consumed by erosion, but there is considerable evidence that *Phragmites* formerly grew abundantly hereabouts.

The clearest evidence comes from the field notebooks and maps (inspected by courtesy of the Lands Department, Melbourne) which were compiled by John Wilkinson, who surveyed the country N. of L. King in 1849. These show the N. jetty covered with 'high reeds and scrub' and a lake shore fringed by 'very wet morass'. Examination of lake-floor mud just off the eroded N. shore of the delta led to discovery of root material and dead stems of *Phragmites*, and this suggests that the 'very wet morass' consisted of reeds spreading into the lake. The 1849 map show similar morass on the NW. fringes of Jones Bay, where reed growth persists. Fig. 3 includes a map of the probable form of the delta in 1849, based on evidence from Wilkinson's maps and notebooks. Howitt's description, already quoted, and Gregory's account suggest that this form persisted until the turn of the century, but since then the reed fringe has almost entirely disappeared, and erosion has developed; in 1959 (Fig. 3) the delta was clearly in course of decay. At one point the S. jetty was scarcely wider than the track which leads to the fishermen's settlement at the E. end, and a break-through here was imminent.

Large quantities of sediment are still carried down by the Mitchell, particularly during floods, but much of it goes out through The Cut into Jones Bay. It is significant that, in the absence of a reed fringe to trap the sediment, there is very little in the way of silt jetty formation here. Most of the sediment is carried out into Jones Bay and deposited on the lake floor. The growth of silt jetties therefore depended upon the presence of *Phragmites* around the river mouth and along the lake shores, trapping sediment and shaping the form of the delta. The digitate form must be attributed to the fact that the NW. corner of L. King is very well sheltered from both westerly and easterly winds; the cusped deltas of the Latrobe, Avon and Tambo have grown in face of rather stronger wind-generated waves. It is very likely that the Tambo delta also formed in the presence of a reed fringe, and that the continued growth of the Latrobe and Avon deltas depends on the persistence of a reed fringe along their shores.

Reed Growth in the Gippsland Lakes

In a recent paper the author analysed the distribution of shoreline reed growth around the Gippsland Lakes at the present time in comparison with evidence of its former extent (Bird 1961). It was found that reed growth has been considerably reduced in the last 40 years, and the most likely explanation of this is an increase in the salinity of the lake water to levels above the salinity tolerance of *Phragmites communis*; none of the other possible explanations considered fitted the facts as well. Surveys carried out by the State Rivers and Water Supply Commission showed that the pattern of salinity in the Gippsland Lakes is determined largely by the influx of fresh water from the rivers and the influx of sea water through the artificial opening at Lakes Entrance, cut in 1889. The salinity regime is seasonal. In late winter, particularly after serious river flooding, the lakes are almost fresh but at the end of a dry summer they are brackish, and even in L. Wellington, the lake that lies farthest from the artificial entrance, salinity attains level between a quarter and a third of the salinity of Bass Strait (about 35‰ NaCl). Reed growth survives in L. Wellington, and in certain sites remote from the artificial entrance, particularly near the mouths of fresh-water creeks. It follows that the lake water has become too saline for *Phragmites* growth around much of the shore of L. King, and certainly on the shores of the Mitchell and Tambo deltas. The invasion of splashed pastureland by salt marsh plants is another indication of high salinity.

This change in the salinity regime of the lakes is almost certainly a consequence of the opening of the artificial entrance, which permitted much freer influx of sea water to the lakes than could have taken place formerly. Under natural conditions, prior to 1889, a pre-existing natural outlet from the lakes E. of Lakes Entrance township was frequently sealed off by a sand barrier in the summer months, and this would have excluded sea water at the season when it now enters very freely. Die-back of *Phragmites* has revealed that an intimate balance existed between sedimentation and ecological conditions; if a reed-fringe had not existed, river deltas of the type now seen could not have developed and a very much larger proportion of silt brought down by the rivers would have been carried out into the lakes and deposited in deeper water.

Conclusion

As a rule the formation of river deltas is simply due to the accumulation of superabundant sediment at river mouths, but in the Gippsland Lakes this accumulation depends on the presence of a reed fringe. The river deltas of the Gippsland Lakes thus offer a remarkable instance of the physiographic significance of ecological conditions. It is well known that vegetation can bring about modifications in physiographic development; a vegetation cover can stabilize blowing sand in fixed dune forms and a change in vegetation can lead to accelerated erosion on slopes. Reed growth can promote swamp encroachment on the shores of lakes and estuaries and halophytic vegetation can aid the build-up of salt marshes. The instance of reed growth playing a vital role in the growth of river deltas, to the extent that in its absence they would not exist, is probably rare. Such features are inevitably sensitive to changing ecological conditions, a point that is well illustrated by the present condition of deltas formerly built by the Mitchell, the Nicholson, and the Tambo. Their persistence or revival could take place only if the lakes became freshened so that *Phragmites* could spread to its former extent and resume its

former role, or if some salt-tolerant shoreline reed, possibly one of the species of *Spartina*, invaded the lakes and took over the role formerly played by *Phragmites*.

Acknowledgements

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Explanation of Plates

PLATE VIII

- Fig. 1—The silt jetties of the Mitchell delta winding into L. King.
Fig. 2—The eroded southern shore of the Mitchell delta.

PLATE IX

- Fig. 1—The eroded delta at the mouth of the Tambo R.
Fig. 2—The reed-fringed delta at the mouth of the Latrobe R.





THE SALT LAKES OF LINGA, VICTORIA

By R. F. CANE, DSC, FRACI

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Summary

The Salt (Pink) Lakes near Linga in Victoria are described and information is given on the nature and topography of the area. The character of the salt deposits and some features of the annual salt cycle are discussed in detail and an explanation is put forward regarding the occurrence of the 'black mud'.

It is shown that previous data on the nature of the underlying lake structure are in error and it is also demonstrated that there is a regular change in the lakes' composition both temporarily and with varying depth.

The spectacular seasonal pinkness of the lacustrine water is shown to be caused by the presence of enormous quantities of a microscopic halobiontic biflagellate phytozoan containing about 40% of its dry body weight of the red polycene pigment, β -carotene.

Introduction

The Pink Lakes near Linga in the county of Weeah, NW. Victoria, are an important source of salt for industry and, although salt harvesting by various operators has been carried on for nearly a century, comparatively little is known about the exact conditions of the deposition of salt, the annual changes of brine level, and the nature and composition of the underlying salt formations. With these unknowns in mind, it was decided in 1950 to collect together information of general interest and, at the same time, initiate a programme of experimental work which should, over a period, provide precise information on the character of these interesting deposits.

Other data of a less technical nature may be found in articles by Bain (1947) and by Barrett (1936).

General Background

The Pink Lakes of the Victorian Mallee lie in the semi-desert region of NW. Victoria, about 260 m. NW. of Melbourne (Fig. 1). The lakes are about 8 m. N. of Linga and Underbool (Fig. 2), which are small towns situated on the railway running W. from Ouyen through Pinaroo to Adelaide. In this area there is a series of small lakes or lagoons running NW. from Underbool. These lakes are described in some detail by Hardy (1914, 1936) although he mentions that they had been on the map for some time under the general name of 'Salt Lakes', salt being produced from them as far back as 1866. Most of the lakes are insignificant, but some are of importance, not owing to size, but because of commercial salt recovery. The main lakes are made up of 3 brine areas called:

- Sailor L. or L. Becking or A lake
- L. Crosby or Gye's L. or B lake.
- Crescent L. or Home L. or C lake.

Other minor lakes have been named, e.g. L. Poulton, a mile or so W. of L. Crosby.

Considerable uncertainty exists regarding the areas of the lakes because the numerous near-flat gravelly beaches and surrounding swamps make impossible any sharp demarcation of shore-line. In addition, because of the flat terrain and shallowness of the lakes, even mild wind causes significant changes in the contour of the water. Perhaps the most reliable data are those of Owen (1943) who gives the areas as:

Sailor L.	.. .. .	168 ac.
L. Crosby ..	.. .. .	260 ac.
Crescent L.	.. .. .	218 ac.



Fig. 1—Western Victoria showing Mallee region and the position of the salt lakes.

The 3 main lakes are not identical in composition and, as will be demonstrated later, several features of the brine of one lake usually distinguishes it from the others.

Topography

The position of the lakes is shown in Fig. 2 and 3, and a short description of the area follows. The country is sparsely vegetated and consists of undulating sandhills and patches of loose drift sand. The rainfall varies between $7\frac{1}{2}$ " and 17" annually with an average of 12", whereas the annual net evaporation is about 40". The average summer maximum temperature is about 90°F, while the average minimum is 60°F. Each lake is surrounded by a ring of gypseous sand dunes covered with open low scrub, the dunes being noticeably higher and more abrupt on the W. margin. The area is barely covered with low scattered vegetation including *Atriplex*,

Spinifex, *Melaleuca*, *Callitris*, occasional *Casuarinae* and various mallee eucalypts and acacias. Some of the dominant flora has been attacked in recent years by the parasitic mallee vine. A detailed description of this and the surrounding area has been given by Hardy (1914). It must be remembered, however, that since this description, some important species have been ravaged by parasitic attack; to-day

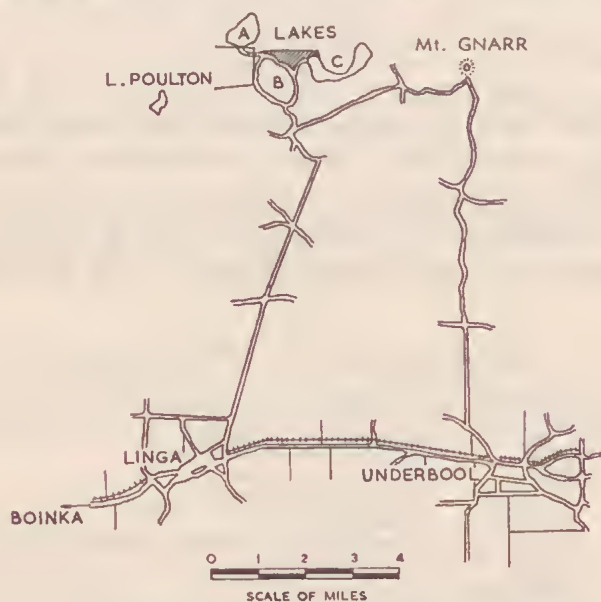


Fig. 2—Salt lakes area, Shire of West Walpeup.



Fig. 3—Salt lakes area showing surface contours—Victorian Railways Datum (after Gloe 1947).

specimens of the *Fusanus* and some acacias are few. The beaded glasswort (*Salicornia*) is found at the lake edges.

Hardy (1914) in his earlier paper states the pink colour of the lakes is caused by chemical impurity in the salt, but later information ascribes the colour to a microscopic pink flagellate. Localized greenish, red and orange patches are of vegetative origin and consist mainly of colonial algae (Hardy 1936).

The area is within the Tertiary Murray Artesian Basin and is just outside the area of useful artesian water as defined by Gloe (1947). There are many brackish bores in the area, the static head of which corresponds nearly exactly to ground level; some of these bores are highly saliferous, but there seems no connection between the artesian and the lakes' waters. Ground water in the sand cover is also appreciably saline.

Underlying the lakes is approximately 200 ft of sand followed by a further 200 ft of clay and limestone. A representative bore log is shown in Table 1 which has been assembled from various sources (Chapman 1916, Gloe 1947, etc.).

TABLE 1
Bore Log of Mallee Bore (W. Walpeup)

Depth (ft)	Record
4-14	Reddish sand and loam
14-21	Fine grained sand
21-56	Fine yellow sand
56-80	Quartz grit
80-114	Sand, quartz, granitic and dune sands
114-120	Clay with shells
120-154	Coarse sand
154-161	Sand with shells
161-245	Sand
245-320	Blue clay and shells (Kalimnan clays)
320-430	Bryozoan limestone
430-468	Blue clay
468-520	Limestone
600+	Brown black lignitic clays
900+	Bed rock of black flint

Description of the Lakes

The 3 main lakes which make up the Pink Lakes have been well described by Owen (1942) and the following general description has been taken mainly verbatim from his report:

SAILOR LAKE

'The lake is roughly pear-shaped in plan tapering to the north. The eastern shore is gently sloping and carries Mallee and Casuarinas. The western shore is flanked by sandhills and steep banks vegetated with Mallee and Spinifex.

There are narrow sandy beaches around most of the perimeter of the lake, but on part of the western and southern margins the shore is formed of ropy masses and nodules of granular gypsum associated with thick deposits of black slimy mud. The masses are soft and spongy to the touch and apparently have been formed by the deposition of gypsum and subsequent bacterial decomposition.'

This mud is discussed later in this report. On the W. dry bank are embedded many crystals of selenite.

Under the influence of prevailing southerly and westerly winds the brine in the lake is driven towards the N. end and consequently a thicker crust of annual salt results near the N. and NE. banks

CROSBY LAKE

'This lake is rather similar in shape to Sailor Lake and lies about half a mile south-east from it.

There are gently sloping banks on the northern and eastern sides, and steep banks and small cliffs on the other sides. The western banks consist of sharp sandhills containing gypsum which outcrops about eight or ten feet above the lake level.'

The W. edge of the lake is covered with slimy black mud throughout the year; this mud is up to 2 ft thick. During early spring, the mud gradually extends from this area until it covers the whole lake. Obvious water seepage is also from this general direction.

In other respects, L. Crosby appears to be very similar to Sailor L.

CRESCENT LAKE

'This lake has a total area of about 240 acres and consists of two limbs a mile apart and connected at their southern extremities by a relatively narrow neck. Each limb has an area of about 140 acres and the whole lake presents in plan the form of a wide letter U open to the north. The western portion of the lake is rather inaccessible on the northern, eastern and southern sides.'

ORIGIN OF THE LAKES

The occurrence of lakes in the NW. Mallee is thought to be associated with shallow depressions caused by the 'solution of underlying beds of limestone and gypsum' (Gloe 1947), but the exact reason is by no means certain. Whether the depressions have been formed by sagging or folding is unknown, and only bores in the lake areas could provide evidence on this point. Whatever the origin, there seems little doubt that once the initial water area has been formed, vegetation around the lake would bind the sand and build up the crater-like formations.

It is suggested that these lakes have a structure similar to many lakes in Australia, i.e. shallow depressions covered by a lenticular semi-pervious gypseous mud pan which acts as a supporting table for local rainfall. Whether the mud pan extends over a large area or there is a series of mud lenses is unknown, but calculation shows that a comparatively small catchment would account for the water intake. E.g. between 15 March and 26 June 1952, the brine in B lake increased in depth by $4\frac{1}{8}$ in., the rainfall at Ouyen was 2.4" in May and 1.3" in June. Taking the daily rainfall and allowing a 10% loss (this is considered adequate by the State Rivers and Water Commission) it can be shown that a catchment area of approximately $2\frac{1}{2}$ sq. m. would be sufficient for the increment in level; 60% of such area being provided by the lakes themselves. An examination of Fig. 3 shows that the lakes are in a shallow hollow extending over an area of 28 sq. m. below a reduced level of 175 ft and a much larger area below 250 ft R.L., so that even in periods of high evaporation, sufficient drainage should occur to maintain a supply of brine to the lakes.

The lakes have no visible source of supply of water and no inlet or outlets; water entry is by general seepage from the higher surrounding country. Owen (1942) in his report states—

'The levels of the lake beds approximate closely to the wet season ground water table, with the result that rains of an exceptionally wet winter, such as that just experienced (1942),

do not cause any appreciable rise of the water level in the lakes above that of normal seasons, as it would do if they had impervious bottoms.'

It is shown here that the lakes' level does change with rainfall and moves in sympathy with it (Fig. 5) and it would appear that observers have not given sufficient weight to the effect of wind which will, over such a large flat area, create very great differences in apparent level depending from what direction it blows; the variation of level may amount to several inches within a short period. Although discounted by some, there is little doubt that rainfall is the source of the water and during wet periods small seepages may be seen on the W. banks. Although later information in this paper will show that the water level rises and falls with rainfall, there seems to be a definite time lag between rain and alteration in level. The bands of coarse sand and gravel which are to be found some feet below the banks on the W. and SW sides of the lakes probably act as important aquifers.

The salinity of ground water in this area shows 10-90 gm/litre of chloride and the reason for the salinity has been the subject of several postulates. The retreating Murray Gulf at the end of the Pliocene could have contributed salt which has been brought to the surface by capillary action, but it seems more likely that, at least as far as make-up salt is concerned, the chief source is cyclic, i.e. wind-borne from the sea. (This cyclic salt is always found in semi-desert areas with high evaporation and gentle rainfall so that there is no appreciable run-off and halite plus gypsum remains as a residue from the deposition of sea salt.) In addition, there must be a nice seasonal balance which, with the lowering of the water table in early summer, drains away the bittern containing the magnesium, some sulphate and other more soluble constituents in such a manner that nearly pure sodium chloride is deposited on the surface of the main mass of halite which underlies the brine for a depth of about 4 ft.

This so-called 'annual' salt is deposited on top of the 'permanent' salt, the surface of which corresponds to the level of the summer water-table.

NATURE OF THE SALT

Although the salt horizons have been divided into 'annual' and 'permanent', these terms are rather confusing as some of the upper layer of the permanent salt is dissolved during the winter. However, there is some distinction to be made between the salt which is deposited in any one year and the previous years' residual material lower down.

Although there is variation from place to place in the nature of the salt layers, the following can be regarded as a generalized description and Fig. 4 gives an idealized diagrammatic structure, which has been sketched about half size. Six strata can be seen in the upper portion, an uppermost layer (A) of occasional flaky white 'drift' salt (flake or float salt) followed by a layer (B) of thin crystals, plus the well-known 'hopper crystal' (hollow truncated tetragonal pyramids) characteristic of surface growth (Mendeleeff 1891). Below this are scattered cubic crystals of truly transparent salt (C) found hanging on the bottom of the upper layer and formed by crystals growing downwards from the bottom of the floating rafts of salt. This composite layer is very loosely connected to the next layer and often separated by isolated salt crystals bridging the void. This upper composite layer (ABC) is undoubtedly formed by surface evaporation and commences as an aggregate of floating hopper crystals which forms into a larger raft by surface and sub-surface growth. These salt rafts can be seen floating on the brine during periods of high

evaporation and can reach several square feet in size. After a while, wind or other agency causes the raft to sink, whereupon it 'sits' on the subsurface growth of annual salt.

The next lower layer is a fairly compact mass of metamorphosed cubic halite crystals (D) and, as a rule, varying in size from small at the top to large at the bottom. Below this 'annual' salt is usually a thin seam of brown mud and sand which may contain algae (E); the mud is followed by black semi-fluid mud or slime (F) which varies in thickness from nil to 4 inches.

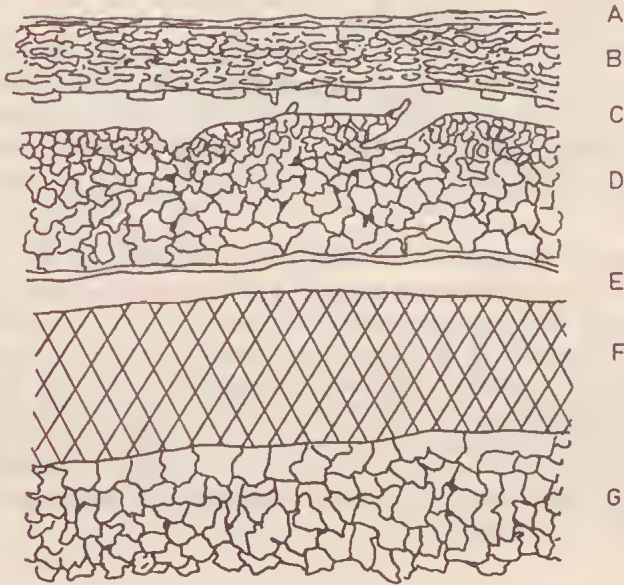


Fig. 4—Section of top layers of salt (diagrammatic).

In some areas of the lakes the black mud extends to the surface and is more or less permanent, especially to the W. from where the brine tends to be diluted; on some W. margins of B lake the mud extends to a depth of 18 in. or more and dead cattle have been observed more or less embedded in it.

Below the black mud is the flat surface of the 'permanent' salt (G), the structure of which is discussed below. The pink salt occurs within band (D), or in (B) when there is an early summer.

By and large, the sequence of events are as follows: The bottom-most mud/salt interface represents the sheared surface from a previous year's salt harvesting and shows appreciable solubility effects during the winter. At the end of the winter, a major area of the lake consists of the permanent salt with a supernatant clear brine solution. At the beginning of the warm period, surface evaporation is not sufficiently rapid to form surface solids but salt begins to form very slowly in the body of the liquid by saturation effects. As the temperature increases, some surface crystals are formed, but the majority are formed still in the bulk of liquid, but at a greater rate, consequently their crystal size is smaller. As small crystals begin to appear at a greater rate, surface evaporation has increased until solid salt in the 'hopper' form appears on the surface; the 'hopper' crystals coalesce forming the

characteristic rafts. The whole process gives rise to the sectional structure described above.

The permanent salt consists of alternating bands of massive clear salt crystals and of dark layers continuing to the bed of the lake about 4 ft deep over a large area. The crystal form and the absence of the 'hopper' variety shows that the 'permanent' salt originated by concentration effects and at no time has there been any major disturbance in its structure. There is no doubt that some of the permanent salt is dissolved during the winter dilution of the lakes, but the main mass of the salt is unaffected as incoming seepage near the top of the salt level tends to stay on the surface because of gravity effects.

The bed of the lake is composed of heavy bluish gypsum clay which provides a semi-pervious claypan for the temporary retention of water. Previous reports state that 'the material down to 4 feet consists of glass-clear recrystallized salt' and there are contradictory statements about its physical structure. Owen (1942) states 'there is much free space probably amounting to 25% of the total volume', while Hall (1943) states that the salt mass is of 'high density and low void percentage'. In actual fact, the porosity of the halite mass depends very much on the season of observation. In order to obtain some unequivocal evidence of the overall nature of the permanent salt, a hole was constructed in B lake approximately 300 yds from the shore. The hole was made by special explosives and a clean section obtained and observed before the brine had a chance of flowing into the hole and disturbing its structure. When a vertical section of the salt was made with a spade, alternate layers of salt and darkish thin seams were seen extending nearly to the bottom of the lake, the dark seams were about $\frac{1}{2}$ in. thick, while the salt strata varied in thickness from $\frac{1}{2}$ in. to 3 in., occasional seams of chocolate coloured mud were also observed. The clay bottom of the lake and the surface mud showed the analyses given in Table 2.

TABLE 2
Analysis of clay and mud (% w/w)

	Black mud	Heavy blue clay
H ₂ O	33.5	10.4
NaCl	21.8	14.5
CaO	2.6	1.4
MgO	1.2	0.2
SO ₃	1.6	1.1
Organic insols.	12.2	4.9
Inorganic insols.	27.5	67.5
{ SiO ₂	5.6	39.5
{ R ₂ O ₃	20.8	11.0
{ Rem.	1.1	17.0

Salt at different depths is given in Table 3.

An inspection of Table 3 shows a regular trend in composition through the depth of the lake, the reason for which will be discussed later.

Although, as mentioned earlier, much of the brine addition is along the surface of the lake, some flows laterally along the salt strata lower down and causes dissolution of the permanent salt at crystal faces and along edges; these solids are

TABLE 3
Analysis of salt from different depths (% w/w—dry basis)

	Drift Salt	Surface Salt	Band 15 in. from bottom		
			Upper	Lower	Bottom
NaCl	99.3	98.0	88.0	74.9	66.3
SO ₄	0.4	0.8	6.0	9.4	12.0
CaO	0.1	0.2	1.3	1.8	3.9
MgO	0.1	0.4	0.1	0.1	0.6
Insolubles	—	9.0	4.6	13.6	18.9

replaced by recrystallization during summer. During the winter period of high voidage, any accumulation of calcium sulphate in the salt tends to settle towards the bottom of the lake. The reason for the stratified light/dark seams in the permanent salt is not at all clear; perhaps there are bands of denser salt which hinder the settling of darker insolubles.

THE OCCURRENCE OF THE BLACK MUD (SLIME)

Black slimy mud is universally found associated with salt in salt lakes, in salt beds and in solar crystallizers. Most rock salt deposits are interstratified with bituminous black sapropelic sediments similar to that of the Linga Lakes.

Black muddy deposits are formed in lakes where water circulation is low and there is a lack of free oxygen in solution. Under such conditions, organic matter is not destroyed but accumulates together with suspended calcium sulphate, iron salts and humic acids. Sulphate-reducing bacteria then attack the gypsum and the resulting calcium sulphide is hydrolysed to the hydroxide with liberation of hydrogen sulphide which precipitates the iron, as well as producing the foul odour associated with these muds.

The black mud is an intimate mixture of decaying organic matter, iron sulphide, humic acid derivatives, calcium sulphate and other inorganic salts characteristic of such matter. In the summer when the brine is saturated, sulphate reducing bacteria can be active no longer and clean salt is deposited.

The quantity and distribution of the mud is very variable and, in some years, its formation is very meagre. In general, the mud is more abundant towards the W. shores of the lakes—the side from which dilution occurs. Some spots within the mud areas yield superb crystals of selenite.

Annual Cycle of Brine

Since the initial publication of data on these lakes nearly a half century ago, there has been considerable difference of opinion regarding the rise and fall of the brine level, alteration of salt level and changes in composition of the brine. In order to provide some reliable answers to these unknown, a series of observations have been made over the last 10 years which will answer some of the above queries.

CHANGES IN THE BRINE LEVEL

Early in 1952, a set of calibrated stakes (150 ft apart) was driven into the salt in a N.-S. direction radially out from an experimental salt plot, 1000 ft from the shore on B lake. The positions of the stakes were fixed and regularly checked by an accurate shore sight. Readings were taken during periods free from wind and

the brine levels recorded at the experimental plot (corrected, if necessary, for any differential between the outer stakes).

Brine and salt levels over a 2-year period are shown in Fig. 5 as well as the monthly rainfall for Underbool, the nearest official weather station. The brine data have been shown as a smooth curve as it is obviously impossible for any sharp discontinuities to occur. The graphs show that:

1. There are regular changes in the brine level.
2. There are similar, although not so pronounced, changes in salt level.
3. The changes are, in a general way, in sympathy with the rainfall although they tend to lag somewhat in time. (*Each month's rainfall has been shown in Fig. 5 at the end of the month, to minimize the apparent time lapse.)

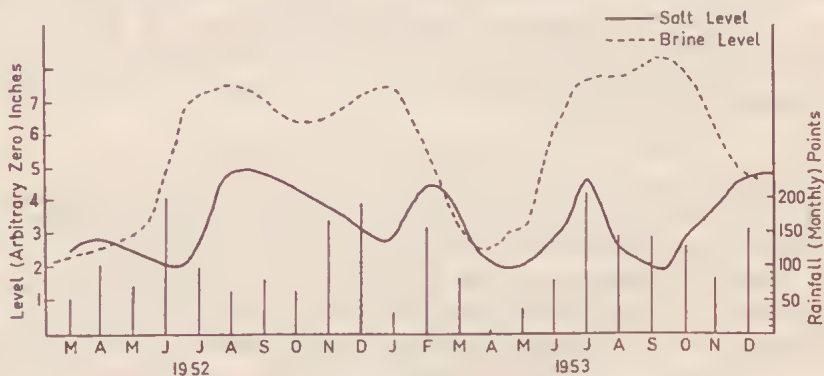


Fig. 5—Changes of level and rainfall with respect to time.

This suggests that subsurface drainage takes a time to reach the lakes proper and that a new influx of salt in solution takes some time to crystallize out. The gradual subsidence in salt level in the late winter seems to be caused by solution of some of the 'permanent' salt as the surface of the salt seemed not very distorted by solubility effects. A sequence of events is visualized as follows:

Rain in May 1952* caused a slow increase in the brine level over May/July, and a corresponding build up of salt over June/August. Little rain between July and September caused a gradual decline in the lake level by surface evaporation, and at the same time, a certain amount of salt was carried away by drainage. More rain in October/November* was shown in the rise in the lake's level, and further dissolution of salt. With an increase in temperature in January, there was a sharp drop in the lake's level, and although the January rainfall was relatively high, it was not shown up in the water level because of high evaporation, but there was a sudden increase in salt level. During March, the level of the brine was below the salt level and harvesting took place. With a decrease in surface temperature and increasing rain in April/May, a certain amount of dissolution and decrease in salt level occurred. However, in June*, with good rainfall, further salt was introduced into the lake with build up in both brine and salt level until July. In the period July/September, moderate rainfall was about equivalent to evaporation, but the surface brine again became unsaturated, with a drop in the salt level caused by dissolution. It seems probable that in a general manner, this cycle is repeated on an annual basis.

THE CHARACTERISTICS OF THE BRINE

Samples of brine from the Linga Lakes were collected during the period 1952/1954 and again in 1960/1961, the writer being absent from Victoria during the hiatus. In most cases 2 samples were taken on each occasion, one at the surface of the brine and another approximately 2 ft down.

With regard to difference in composition between lakes, it would be prolix to give the many hundreds of analytical figures which are available. It may be stated, however, that without any significant exception, the following rules apply:—At any given time, the brine of the 3 lakes shows—

1. a decreasing NaCl concentration in the order—lake A, lake B, lake C;
2. an increasing sulphate concentration in the order—A, B, C—A being about two-thirds of B, and C being about twice A;
3. an increasing brine density in the order of A, B, C, there being little difference between B and C;
4. magnesium increases in the order A, B, C—lake C has considerably more magnesium than either A or B;
5. calcium decreases in the order A, B and C, although there are a few irregularities.

In order to illustrate the generality of 1, 2 and 3 above, it is pointed out that, of 106 analyses done in 1952, only 4 were contrary to the above, and all deviations except one were less than the estimated experimental error.

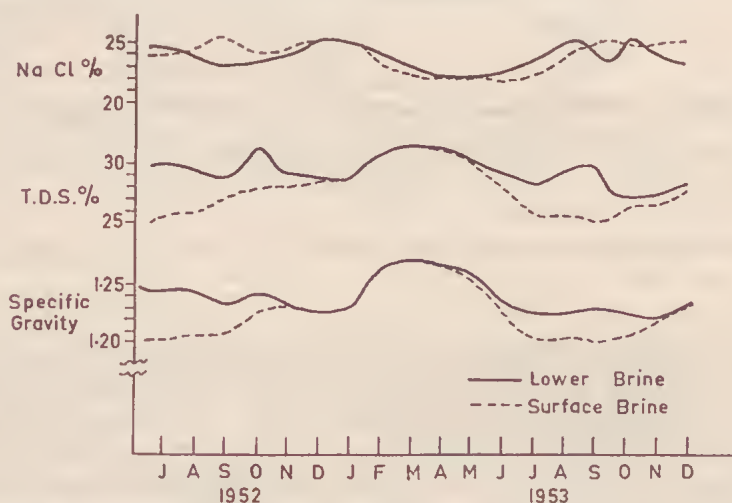


Fig. 6—Graphical representation of monthly changes in certain physical properties of the brine.

Fig. 6 shows the changes in specific gravity and chloride with time; included in the graph is a curve showing 'Total Dissolved Solids' (T.D.S.) determined by evaporation. The specific gravities have been corrected to 20°C using data from the International Critical Tables. The chloride was determined by the standard Volhard analysis and expressed as NaCl. Samples were taken from A lake and B lake, but only B is shown because, with the provisos mentioned above, there is little significant difference between the two. The curves in Fig. 6 cover a period of 1½ years in 1952/53 and although similar data were obtained for the periods

June/December 1958 and for some of 1959/1960, they are not reproduced here as the overall picture is the same and it would be difficult to show the broken shorter periods.

Although the changes in specific gravity and T.D.S. are as might be expected, i.e. show a rise in concentration in the summer and a decrease in winter, the reverse takes place in common salt concentration, the shape of the NaCl % curve being approximately the inverse of the two lower pairs of curves. Furthermore, the brine at the surface of the lake is often greater in NaCl concentration than that lower down. The reason for the apparent abnormality is illustrated in Fig. 7 which shows magnesium and sulphate analyses.

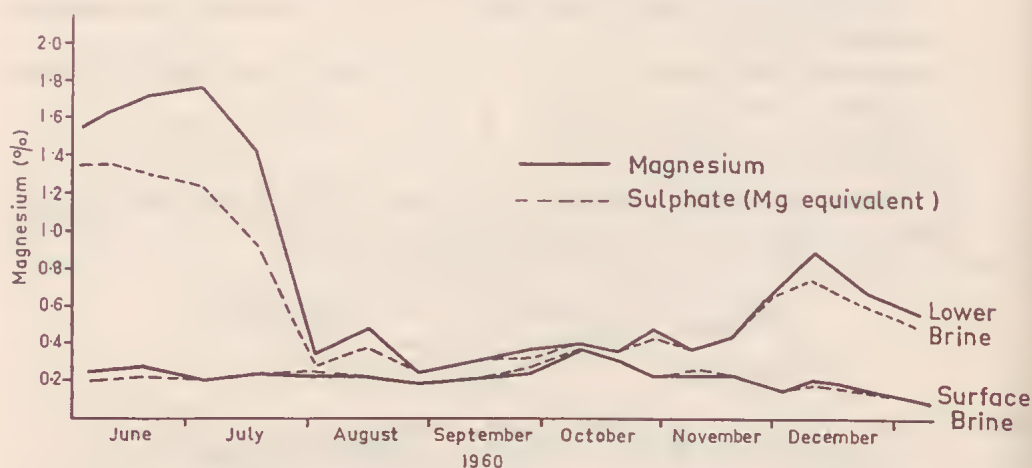


Fig. 7—Changes in magnesium in the brine related to sulphate content.

From the similarity of the graphs, it may be accepted that sulphate ion is introduced to the lakes as MgSO_4 . The analysis of the system $\text{NaCl}/\text{MgCl}_2\text{-MgSO}_4/\text{Na}_2\text{SO}_4$ is complicated by the metathesis $2\text{NaCl} + \text{MgSO}_4 \rightleftharpoons \text{MgCl}_2 + \text{Na}_2\text{SO}_4$ and by the lack of equilibrium data in the temperature range $10\text{-}20^\circ\text{C}$ for the concentrations under consideration. Information from this survey reveals nevertheless that NaCl is not the only compound playing an important role in the brine system of the lakes (in March 1952, MgSO_4 reached 6.7%), that the chemistry of the surface waters differs from that at depth and that a lowering of NaCl concentration does not necessarily mean a more dilute salt solution.

Although all samples were analysed for calcium, the maximum amount present was only 0.06% and the curves followed the T.D.S. curves. It is felt that the calcium salts do not play an important role in the halurgy of the lakes and, for these reasons, it is not proposed to deal specifically with the chemical aspects of calcium.

It would be misleading as regards composition to cite a typical salt analysis as it depends so much on where sampled, at what depth, season, etc. By taking

small samples over a large area and bulking them, an 'average' wet sample showed the following analysis calculated on a dry basis—

NaCl	.. .. .	91.43
MgCl ₂	.. .. .	1.97
MgSO ₄	.. .. .	4.30
CaSO ₄	.. .. .	0.73
KCl	.. .. .	0.04 ?
Inorganic insols.	.. .. .	0.59
Organic insols	.. .. .	0.02
n.d.	.. .. .	0.82

The Red Colouring Matter

The occurrence of living colouring matter in salt lakes, saline ponds and puddles is well known to workers in this field, but is little known outside it. The colour of the Linga Lakes has been variously attributed to mineral matter (manganese and iron), algae, bacteria and optical effects. It has now been proved that the pink colour is caused by a large seasonal population of the biflagellate halophilic phytozoan, *Dunaliella salina* Dun. (Teodoresco 1904), a most interesting alga which is fairly common in similar environments throughout the world.

D. salina was first described by Hamburger (1905) and later in detail by Lerche (1937). Although somewhat curious in that it lives in strong brine, perhaps the most extraordinary feature of the metabolism of *Dunaliella* is that it secretes either chlorophyll or carotene depending on the salt concentration of its environment. Fox and Sargent (1938) state—

'Synthetic brines containing 15% NaCl plus traces of nutrient salts, inoculated with the halophyte, produce flourishing cultures of brilliant green colour, whilst in similar cultures containing 25% NaCl, an actively multiplying population of the same species is of a brick red colour. Intermediate concentrations of NaCl give rise to intermediate variations in colour.'

The red colour of *Dunaliella* is caused by large amounts of β -carotene which is easily extracted from the organism en masse by shaking the red coloured brine with ether from which the polyene crystallizes in superb ruby-coloured glistening platelets. The organism has a specific gravity less than that of the brine and, as it shows positive photo-taxis (Blum 1933), tends to accumulate on the surface and in quiescent pools may congregate until the brine has the consistency and colour of tomato soup. During October 1960, the lakes showed a high pinkness and several gallons of the supernatant red scum were brought to Melbourne for examination. Microscopic examination showed beyond doubt that the colour of the 'Pink Lakes' is caused by *Dunaliella salina* and that, in the material examined, β -carotene occurred to the extent of about 40% of the body weight of the organism.

What local circumstances are responsible for the occurrence of what must amount to tons of the alga in one year and its absence in another is unknown. Its growth, however, is fairly ephemeral, as 2 weeks after the above samples were collected, the lakes had lost their colour and no local concentrations of the halophyte could be seen.

An interesting side-light to this work was the occurrence of a persistent sweet violet-like odour in the salt heaps, caused by the presence of β -ionone from the decomposition of the algal carotene.

Acknowledgements

The writer would like to acknowledge the field work of Mr J. Calland of Ouyen without whose assistance this work would not have been possible. He would also like to express his gratitude to Imperial Chemical Industries of Australia & New Zealand Limited for permission to publish this work.

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CONTACT METAMORPHISM AT BIG HILL, BENDIGO, VICTORIA

By F. C. BEAVIS

[Read 13 July 1961]

Abstract

Thermal metamorphism on the granodiorite contact at Big Hill, S. of Bendigo, is restricted to an aureole less than 1 mile wide. Three zones of metamorphism are recognized: spotted slates, biotite andalusite hornfels, and cordierite hornfels. Selective development of andalusite and apparently restricted development of cordierite in the medium grades are noted. Control of the former is uncertain; the latter is a feature of the retrograde activity which followed the progressive thermal metamorphism.

Introduction

During a study of the structure of the Harcourt-Maldon granodiorite which is still in progress, a small sector of the contact of the massif with Lower Ordovician sediments 7 miles S. of Bendigo was selected for detailed petrological study. In this sector the sediments are slates and greywackes, with a few thin beds of quartzite. The slates are richly fossiliferous, with the Castlemainian graptolite *Isograptus caduceus* var. *victoriae* the typical form.

Thermal metamorphism of the sediments adjacent to the granodiorite is restricted to an aureole generally less than 1 mile in width. The aureole is marked by a sharp asymmetric ridge—the Big Hill Range—with a short steep slope on the S. and a long gentle slope on the N. The crest of the range is 10 to 30 chains from the contact, in medium grade hornfels. The area is drained by Buckeye Creek and its tributaries; the main stream has a course just inside and more or less parallel to the contact. A similar drainage pattern was noted in the SE. of the massif by Hills (1959) who suggested ring fracture control of the intrusion, particularly when the overall arcuate form of the contact is taken into consideration.

The only published work dealing with the contact at Big Hill is a short paper by J. A. Dunn (1921a) in which a quartzite xenolith from the granodiorite was described. The present paper is a petrological study of the contact rocks.

It is desired gratefully to acknowledge the assistance in the field of Adrian Beavis, and the hospitality of Mr and Mrs Dingfelder of Ravenswood. Thanks are due also to Mr V. Biskupsky who made the chemical analyses.

Petrology

ORDOVICIAN SEDIMENTS

The lithology of the lower Ordovician in the Big Hill area is fairly uniform, with alternating thin beds of slate and greywacke, and occasional quartzites. In the W. part of the area, the carbonaceous graptolite slates become less important than in the east. Dunn (1921b) has described some of the Ordovician sediments from Bendigo, but further description is necessary here.

SLATES

The slates are of two types, one somewhat coarser textured than the other. The coarser type shows the development of pale green chlorite along cleavage

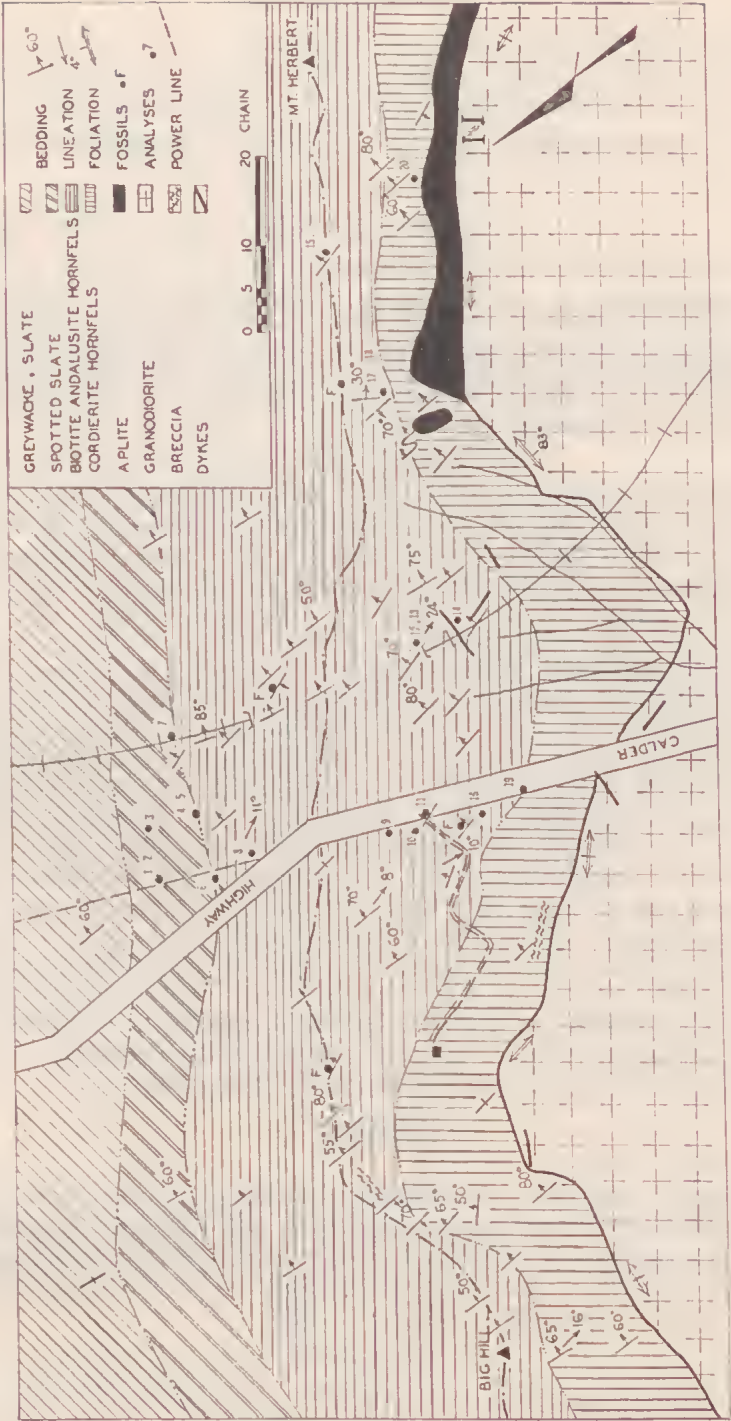


Fig. 1

planes, with sericite abundant throughout the rock. Quartz occurs as minute lath shaped grains, and feldspar, a sodic plagioclase, is relatively common. The finer slate has sericite in considerable excess of chlorite, and contains abundant fine black carbonaceous material. Sometimes relatively large flakes of white mica occur along the cleavage planes.

GREYWACKES

The greywackes are typified by angular to subangular, subequidimensional to elongated sliver-like grains of quartz which show marginal development of authigenic sericite. Some of the quartz grains are dusty with minute black inclusions. These may have a random arrangement, or may form fine parallel trains. Feldspar is common, with sodic plagioclase in excess of orthoclase. The feldspars are angular but do not form sliver-like laths. Thin flakes of biotite and lesser muscovite occur. The matrix consists of fine sericite and a little chlorite, the latter as blades and shreds, light green in colour. Isolated flakes of chlorite occur with black iron ore about the margins. Some fine quartz and feldspar are present in the matrix. The only carbonate present is rare ankerite. Detrital subrounded zircon and tourmaline are frequent.

QUARTZITES

The pure quartzites are composed almost exclusively of angular to subangular quartz grains, with an outer rim of secondary quartz. Some white mica and small grains of feldspar occur rarely; heavy accessories are sometimes abundant with zircon particularly important.

TABLE 1
Chemical Analyses of Sediments

	1	2
SiO ₂	88.32	63.30
Al ₂ O ₃	6.12	15.68
Fe ₂ O ₃	2.00	5.70
FeO	0.94	1.10
TiO ₂	0.62	0.79
CaO	0.87	0.95
MgO	0.78	3.15
Na ₂ O	1.48	1.79
K ₂ O	1.25	3.07
H ₂ O+	1.78	3.60
H ₂ O—	0.32	0.61
Total	99.48	99.74

1 Greywacke, Crusoe Reservoir, Kangaroo Flat

2 Slate, Crusoe Reservoir, Kangaroo Flat

Analyses: V. Biskupsky

INTRUSIVE ROCKS

GRANODIORITE

The granodiorite in the contact area shows little variation from that further S. at Harcourt (cf. Summers 1914, Baker 1942). Locally, on the contact, a type of rapikivi texture may be noted, with ovoid phenocrysts of orthoclase, 1 cm in diameter, rimmed with oligoclase, and set in a matrix of oligoclase, quartz and biotite. Generally, however, the texture is normal, hypidiomorphic, with maximum crystal size 3 mm. Quartz is abundant, and is invariably anhedral. Oligoclase-

andesine may be slightly in excess of orthoclase (1.3:1—1:1). The oligoclase-andesine is euhedral to subhedral, and is usually zoned, with the cores more calcic, and sometimes kaolinized. The cores may be strongly poikilitic, with small inclusions of zircon and apatite. The biotite is of two types: one pale green-brown and strongly pleochroic, the other, dark brown, almost opaque. This latter type is absent some distance in from the contact. Apatite, zircon, rutile, ilmenite, sphene, cordierite and muscovite are accessory.

Dykes of granodiorite which intrude the metamorphic rocks have a coarser texture than the rock of the main massif, with crystals up to 5 mm long. Quartz occurs as large anhedral pools, but some smaller euhedral quartz crystals may be enclosed in the large poikilitic plagioclase crystals. The plagioclase is sodic andesine, and is frequently kaolinized. The orthoclase, which is subordinate to the plagioclase, shows little or no alteration. In almost all cases, the biotite has been metasomatically replaced by clinozoisite.

APLITE

The aplite of the Mt Herbert dyke has a fine (0.7 mm) saccharoidal texture. Dark minerals are rare; a few fine flakes of chloritized biotite and some secondary clinozoisite were noted. Quartz and felspar are the main constituents. The quartz invariably is anhedral. Orthoclase is in excess of oligoclase-andesine, which sometimes shows micrographic intergrowth with the quartz.

Other aplite dykes observed were frequently too weathered for examination. Two studied in thin section were identical in texture and composition with the aplite of the Mt Herbert dyke.

TABLE 2
Analyses of Intrusive Rocks

	1	2	3
SiO ₂	70.94	70.65	76.22
Al ₂ O ₃	13.99	12.54	11.66
Fe ₂ O ₃	0.35	0.52	0.99
FeO	3.02	3.59	0.11
TiO ₂	0.58	0.46	0.24
CaO	2.35	2.11	0.59
MgO	0.80	0.85	0.34
Na ₂ O	3.94	3.01	2.72
K ₂ O	3.66	4.15	5.22
H ₂ O+	0.32	0.76	1.34
Total	99.95	98.64	99.43

1 Granodiorite, Harcourt (H. S. Summers 1914)

2 Granodiorite, Calder Highway, Big Hill (V. Biskupsky)

3 Aplite, Mt Herbert (V. Biskupsky)

METAMORPHIC ROCKS

Three distinct zones of metamorphism have been mapped in the Big Hill aureole by the writer. The lowest grade of metamorphism is represented by spotted slates, a narrow zone at the outer margin of the aureole. These slates pass into rocks which, while still spotted, are typified by the development of relatively large flakes of biotite and porphyroblasts of andalusite, with sericite-cordierite aggregates generally present. The highest grade of metamorphism is represented by the zone

of cordierite hornfels, from which andalusite is absent; large porphyroblasts of cordierite are characteristic.

Within the aureole, two features are particularly noteworthy. Except locally, the rocks have a foliated rather than a hornfelsic texture and would be described best as phyllites and semi-hornfelses rather than hornfelses. This is probably the result of the mimetic emphasis of the axial plane cleavage of the pelites. The second feature is the limited degree of recrystallization which has occurred in the low and medium grade rocks. This is illustrated by the preservation of readily identifiable fossils in high grade andalusite-biotite hornfels in which varietal determination of graptolites was possible to within less than 10 chains of the contact.

Spotting is typical of all but the highest grades of the metamorphic rocks and is a macro-feature of the retrograde activity. Although in thin section the nature of the spots is seen to change (Fig. 2); this change is frequently not apparent in the hand specimen.

ZONE OF SPOTTED SLATES

The pelitic rocks of this zone have typically ovoid spots which are aggregates of pale green sericite and lesser chlorite, associated with which may be large poikiloblasts of muscovite. The matrix of the rock is composed of sericite, a little chlorite, fine quartz and sodic plagioclase (? albite), fine graphite and some magnetite.

In the metagreywackes the larger quartz grains are more rounded than in the normal rock, suggesting some marginal solution; some of the quartz grains contain fine needles of an indeterminate mineral. A few grains of sodic oligoclase are present. The matrix shows appreciable recrystallization and consists of fine muscovite, very rare biotite, quartz and feldspar, with sericite abundant. Detrital zircon and tourmaline are relatively common.

In the narrow belt of transition from this zone to that of biotite andalusite hornfels, the metagreywackes show no significant changes. The pelitic rocks, however, do show a more advanced metamorphism, and for the first time there is mineralogical expression of possibly initial compositional differences. Samples taken from adjacent beds may be used to illustrate this point. In one type (Analysis 5, Table 3), the spots, which have irregular outline, consist of fine sericite with minute crystals of cordierite and relatively large flakes of muscovite. The matrix is essentially sericitic with a little fine quartz. Graphite is very rare. In the sample from the adjacent bed (Analysis 4, Table 3) the matrix is similar except that graphite is abundant. The spots, though irregular, are less so than in the first specimen. They may be uniform in composition, when they consist of pale green isotropic material, or they may be zoned, with a core of cordierite or, more commonly, andalusite, surrounded by brown isotropic material and an outer rim of sericite. Associated with the spots are euhedral porphyroblasts of andalusite, usually with a spongy core rich in graphite, pale green mica and sericite, which may also occur about the margins. Almost invariably a rim of graphite occurs on the andalusite porphyroblasts. Rarely, the typical chialstolite cross is present (Fig. 2 (vi)).

ZONE OF BIOTITE-ANDALUSITE HORNFELS

More or less pure metaquartzites were observed only rarely in this zone; the best exposure noted was on the Calder Highway, near the Big Hill cutting. The metaquartzite has a mosaic texture. The quartz contains fine black inclusions



Fig. 2

as well as fine needles. There are a few crystals of sodic plagioclase. Any intergranular matrix present has been partially recrystallized, and whilst dominantly sericitic, flakes of muscovite and of pale brown, strongly pleochroic biotite are relatively abundant. A little cordierite may be present, with accessory zircon, tourmaline, apatite and magnetite.

The metagreywackes show a marked reduction in feldspar, which is a sodic plagioclase. Biotite, occurring as small strongly pleochroic flakes, is abundant. Cordierite is rarely present. Near the S. portal of the Big Hill Tunnel, a variety of metagreywackes occurs. The larger crystals of the more arenaceous types are exclusively quartz. The matrix is sericite. The more pelitic greywackes show strong development of muscovite in the matrix. These rocks are spotted, with the spots composed of sericite, with minute crystals of cordierite and relatively large flakes of muscovite on the margins of the spots.

The pelitic rocks show some more or less consistent changes across this zone. Near the N. portal of the tunnel the rocks are spotted: the spots are sericite-cordierite aggregates up to 1.5 mm long, frequently with cores of cordierite. Relatively large flakes of muscovite are present both in the spots and in the matrix. The muscovite has a poikiloblastic habit, with small inclusions of cordierite. Sericite, quartz and muscovite constitute the matrix. Near this rock, a similar type occurs except that muscovite and cordierite are reduced, and biotite becomes important. On the crest of the ridge above the tunnel, alteration is more advanced. Here, two distinct types of hornfels were recognized. One type has weakly developed spots of sericite with small cordierite crystals and well-formed flakes of muscovite. Some of the spots have a crude zonal structure, with graphite rich cores. The matrix is composed of quartz, rare feldspar, sericite and graphite. This rock is of interest since it is unusual for graphitic pelites in this zone to contain no andalusite. The other type has well developed graphitic spots, which have cores of cordierite and an outer zone of sericite. Some large flakes of muscovite occur in the spots. Anhedral cordierite with inclusions of fine graphite is present while anhedral to subhedral porphyroblasts of andalusite are abundant. Some of the andalusite shows replacement along margins and cleavage planes by a pale green fibrous ? chloritic material.

Near the centre of the zone, the typical biotite andalusite hornfels reaches the peak of its development. The rocks are spotted; the spots, 2 mm long, have irregular outlines, and are sericitic with fine inclusions of cordierite, and trains of graphite. Subhedral to euhedral porphyroblasts of andalusite are abundant. Some have spongy cores enclosing fine flakes of biotite (Fig. 2 (iv)). Sometimes the andalusite, though abundant, occurs as very small euhedra.

On the spurs rising from the contact to Mt Herbert, rocks transitional to the cordierite hornfels zone are exposed. Spotting is still typical, but the spots consist of small flakes of muscovite and have graphite rich cores. Euhedral andalusite is almost completely replaced by green ? chloritic material. Replacement has sometimes been from the outer margins and sometimes from the cores (Fig. 2 (vii)). The matrix is rich in fine muscovite, lesser biotite, fine quartz and graphite.

ZONE OF CORDIERITE HORNFELS

The development of definite porphyroblasts of cordierite and biotite and the complete absence of andalusite are typical of rocks of this zone, which tend more to the true hornfelsic rather than foliated textures. Locally, true hornfelsic texture is fully developed.

A series of metaquartzites from the contact illustrates the highest grade of metamorphism of the pure arenites. One type, from 10 chains W. of the railway line consists of a mosaic of anhedral quartz with fine flakes of biotite developed about the margins of each crystal (Fig. 2 (x)). The quartz has abundant fine black inclusions which have a more or less random distribution. A similar type from the contact with the aplite dyke shows the quartz crystals in direct contact with each other, with sutured margins. A metaquartzite adjacent to this is notable for the development of superindividuals (Fig. 2 (viii)). These are large (4-8 mm) crystals with small inclusions of zircon and biotite and fine black inclusions forming a pattern suggesting that these define the pre-recrystallization margins of smaller crystals. Optical continuity exists throughout large individuals. In all of these rocks, any pelitic matrix has been recrystallized and consists of biotite, muscovite and cordierite.

The metagreywackes of this zone show advanced recrystallization of both the large grains and the matrix. Except in the very highest grades, there is still a tendency to spotting. The spots are 1.5 mm long and most are composed of an indeterminate cryptocrystalline to glassy material. Some, however, are sericitic with well developed flakes of muscovite. They may have rims of cordierite. The large quartz grains are well rounded. Some orthoclase is present. The matrix of the rock contains anhedral porphyroblasts of cordierite, muscovite, green biotite and minute feldspars.

In the pelites, spots are generally but not invariably absent. Subhedral to anhedral porphyroblasts of cordierite are abundant, all of which, in specimens adjoining the contact, have been pinitized. Large flakes of muscovite are common, but biotite is rare. The abundance of secondary tourmaline in some of the rocks suggest that pinitization of the cordierite may have been due to pneumatolytic activity. Somewhat closer to the contact the rocks have elliptical concentrations of poikiloblastic cordierite, with fine inclusions at the cores. Surrounding these poikiloblasts are flakes of biotite and large flakes of muscovite which otherwise is not common.

A specimen from Big Hill is one of the few true hornfels observed. The rock is dominated by irregular elliptical poikiloblasts of cordierite. Included in the cordierite are small flakes of pale, strongly pleochroic biotite, needles of ilmenite and rare tourmaline. Biotite frequently surrounds the cordierite; pale yellow cordierite, showing polysynthetic twinning may be associated with the biotite. The matrix of the rock is composed of cordierite, biotite and quartz. A series of hornfels from the contact at Mt Herbert contain elliptical aggregates of muscovite with cores of cordierite. The matrix consists of cordierite, muscovite, green biotite, quartz and rare feldspar.

An unusual type from the contact at Big Hill homestead is essentially a green biotite-muscovite-sericite rock. Muscovite occurs as large poikiloblastic flakes, with minute inclusions of cordierite. These sometimes occur as elliptical aggregates intimately associated with cordierite poikiloblasts, the whole surrounded by a rim of chlorite. Sheaves of green biotite are abundant, while white tremolite occurs in significant proportions.

XENOLITHS

Xenoliths are rare on the Big Hill contact. The most important is that described by Dunn (1921a). A few small arenaceous types were also observed near Big Hill.

TABLE 3
Chemical Analyses of Metamorphic Rocks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SiO ₂	89.50	79.89	86.13	69.58	64.45	54.25	70.85	67.80	72.52	55.98	63.95	66.38	60.55	62.59	68.89	61.25	64.75	60.33	68.49	98.67
Al ₂ O ₃	4.78	8.68	3.99	12.68	16.92	23.34	13.86	14.45	13.35	5.85	20.10	15.15	19.10	15.63	18.65	23.48	16.25	15.45	15.05	0.88
Fe ₂ O ₃	1.01	1.88	3.81	4.61	4.49	5.70	3.04	4.89	3.01	1.91	2.09	4.42	4.80	6.40	1.26	2.04	4.12	12.02	4.01	0.09
FeO	0.49	1.04	1.00	0.34	0.24	1.10	0.26	0.83	0.66	0.08	0.71	0.44	0.64	0.50	0.26	0.36	1.24	0.64	0.35	—
TiO ₂	0.41	0.47	0.61	0.55	0.58	0.95	0.54	0.74	0.41	0.20	0.40	0.59	0.60	0.83	0.54	0.61	0.59	0.12	0.43	0.47
CaO	0.65	0.65	0.75	0.50	0.41	0.60	0.56	0.74	0.41	0.61	0.59	0.54	0.65	0.52	0.56	0.37	0.52	0.27	0.49	0.37
MgO	0.20	0.42	0.41	0.38	0.25	3.19	0.65	1.43	0.69	0.30	—	0.53	0.98	0.73	0.32	0.63	0.82	0.80	0.84	—
Na ₂ O	0.98	0.95	0.64	0.81	0.61	0.65	0.51	0.64	0.86	1.83	0.53	0.46	1.00	1.45	0.51	1.09	0.80	0.80	0.55	0.10
K ₂ O	0.91	2.20	0.89	4.20	4.85	3.75	4.29	2.96	3.23	0.83	3.15	4.23	4.80	4.86	4.65	3.41	4.65	4.29	3.21	0.12
C	—	—	tr.	1.10	0.10	1.80	0.80	—	0.57	—	0.40	1.00	—	—	tr.	—	tr.	tr.	0.54	—
H ₂ O+	1.21	2.76	2.18	4.90	6.48	4.18	4.10	4.58	3.23	1.42	7.25	5.15	5.40	4.98	4.76	5.05	4.38	5.48	5.27	0.30
Total	100.14	98.94	100.41	99.65	99.38	99.51	99.38	99.06	98.94	99.01	99.17	98.86	98.52	98.49	100.40	98.29	98.12	100.77	99.23	100.39

Analyses: V. Biskupsky

Zone of Spotted Slate:

- 1 Metaquartzite
 - 2 Quartz-felspar-sericite metagreywacke
 - 3 Quartz-muscovite-sericite—(graphite) metagreywacke
- Transitional between Zone of Spotted Slate and Zone of Biotite—Andalusite Hornfels:

- 4 Spotted andalusite-sericite—graphite—(cordierite) hornfels
- 5 Sheared quartz-sericite-muscovite hornfels
- 6 Quartz-andalusite-cordierite-sericite—biotite—graphite hornfels.
- 7 Quartz-biotite-sericite—andalusite—graphite hornfels.

Zone of Biotite-Andalusite Hornfels:

- 8 Quartz-biotite—(cordierite) metagreywacke
- 9 Quartz-biotite—andalusite—graphite—(cordierite) hornfels

- 10 Quartz-biotite-muscovite-sericite metagreywacke
 - 11 Spotted chlorite-sericite—andalusite—graphite hornfels
 - 12 Biotite—andalusite—graphite hornfels
 - 13 Quartz-sericite-muscovite—(andalusite) hornfels
 - 14 Quartz-sericite-muscovite-cordierite metagreywacke
 - 15 Spotted sericite—andalusite—graphite-quartz hornfels
 - 16 Quartz-biotite—(cordierite) hornfels
 - 17 Quartz-sericite-muscovite—andalusite hornfels
 - 18 Quartz-muscovite-sericite—chlorite hornfels
- Transitional between Zone of Biotite-Andalusite Hornfels and Zone of Cordierite Hornfels:

- 19 Quartz-muscovite-biotite-sericite—cordierite hornfels
- 20 Metaquartzite

For localities of analysed specimens, see Fig. 1.

The xenoliths consist of a fine mosaic of quartz with some rare andesine and rarer orthoclase. Biotite is relatively abundant about the margins of the quartz. This is usually pale brown and strongly pleochroic. Cordierite is absent. Fine needles of sillimanite occur; these are frequently, but not invariably, enclosed in the quartz.

Discussion

The mineral assemblages of the metamorphic rocks are shown on Table 4. The true nature of the original parent rocks is uncertain since these had been raised to the 'Chlorite Zone' during folding which predated the thermal metamorphism.

TABLE 4
Mineral Assemblages of Metamorphic Rocks

Mineral	Parent Rock	Spotted Slate	Biotite-Andalusite Hornfels	Cordierite Hornfels	Xenoliths
Quartz					
Plagioclase					
Orthoclase					
Sericite					
Chlorite					
Muscovite					
Green Biotite					
Brown Biotite					
Andalusite					
Cordierite			(.....)		
Graphite					
Tremolite					
Sillimanite					

Consideration of both the chemical composition and mineral assemblages of the rocks indicates immediately that, in spite of varying mineralogy, chemical compositions of both the pelitic rocks and greywackes are constant across the aureole. The association of graphite with andalusite and the restricted development of the latter mineral may be noted also. Generally, within the zone of biotite andalusite hornfels, the andalusite occurs as large cores to the ovoid spots or as euhedral porphyroblasts; occasionally it is present as very fine crystals disseminated throughout the rock (as, e.g. in the hornfels of analysis 6).

The examination of analyses 4 and 5, 12 and 13, and 17 and 18 suggested initially that some chemical difference might account for the selective development of andalusite since, for each of these pairs, from adjoining beds, and therefore subject to the same metamorphic conditions, one member contained andalusite, while this was absent from the other. In one case (analysis 5) the effect may have been due to localized shearing, and in another (18) metasomatism had occurred, so these comparison were not valid. Pitcher and Read (1960) have suggested that, while andalusite is typically the low temperature silicate, it might develop only in rocks of special composition, i.e. pelites rich in FeMg relative to available aluminium, where possibly the concentration of the divalent ion in, say, biotite, may influence the growth of a particular aluminium silicate. Pitcher and Sinha (1958) showed that in the Ardara aureole, rocks with abundant andalusite are relatively richer in magnesia.

Table 5 shows the mean compositions of the metapelites from the zone of biotite andalusite hornfels in the Big Hill aureole.

TABLE 5

	A	B
SiO ₂	65.73	62.15
Al ₂ O ₃	17.05	17.87
Fe ₂ O ₃	3.67	6.23
FeO	0.62	0.43
TiO ₂	0.59	0.53
CaO	0.54	0.39
MgO	0.84	0.60
Na ₂ O	0.68	0.98
K ₂ O	4.10	4.35
C	0.63	—
H ₂ O+	4.81	5.49

A Andalusite hornfels; B Hornfelses containing no andalusite.

The application of tests showed that the statistically significant differences are the higher Fe₂O₃ and H₂O+ content of the andalusite-free hornfelses, and the presence of C in the andalusite hornfelses. The higher proportion of MgO in the andalusite hornfelses is of only minor statistical significance. Thus there is no definite support for the ideas of Pitcher and his co-workers in the Big Hill aureole. While the andalusite hornfelses usually contain graphite, this is not always so; it is unlikely in any case that graphite would have any active role in metamorphic reactions which produced andalusite, and it is probable that the association is due to the original depositional environment.

The persistence of muscovite throughout the aureole is to be expected in rocks in which sericite is in excess of chlorite (Tilley 1926); this is reflected in the consistently high K₂O content. Similarly, though cordierite persists from the medium grade hornfelses, the weak development of this mineral is due, in part, to the potassic nature of the sediments. Compton (1960) found that in aureoles in the Santa Rosa Range, Nevada, cordierite and andalusite were invariably found together in the metapelites. This is not true of the Big Hill aureole, where, in medium grades, cordierite may occur without andalusite, and in the high grades, from which andalusite is always absent.

In the high grade hornfels, the sericitization of the cordierite is clearly retrograde, and at the contact the replacement of cordierite by muscovite and green biotite is evidence of retrograde metasomatism. In both the medium and high grades, the abundance of spots is also macro evidence for retrograde activity. In the lower parts of the biotite andalusite hornfels zone it is often difficult to assess whether the association of cordierite with ovoid spots of sericite is due to some retrograde reaction or whether it is progressive. Higher in this zone, as well as in the zone of cordierite hornfels, the association is certainly retrograde. The assemblage andalusite-muscovite-biotite appears to be stable in the middle zone and it is almost certain that the cordierite present was involved in the retrograde reaction:

Cordierite + muscovite → biotite + andalusite + quartz.

Metasomatism has played only a minor role in the metamorphism, except immediately adjacent to the contact. It is clear, however, that water was important because of the large size of the biotite, muscovite and andalusite crystals, the water content of the rock (much higher than in the unaltered sediments) and the generally very high Fe₂O₃/FeO ratios. Other aspects on which comment is neces-

sary are firstly, the presence of tremolite in one contact hornfels, due to at least one pelitic bed being richer in lime than the majority; secondly, the abnormally high (12%) Fe_2O_3 content of the rock of analysis 18. This rock has a more or less normal mineralogy—quartz, rare feldspar, sericite, but chlorite is more important than usual and fine hematite is disseminated abundantly throughout the rock, indicating local iron metasomatism close to this part of the contact.

Comparison of the Big Hill aureole with those at Tooborac (Singleton 1944) on the Cobaw massif, and at Bulla (Tattam 1925) shows that in these latter cordierite has developed to a greater degree, while andalusite is absent or rare. While these differences may be in part due to compositional variations in the parent sediments, it would seem that the retrograde activity at Big Hill is the more significant factor, particularly in accounting for the variations in cordierite development. In all three cases, temperatures and pressures were low during metamorphism, with conditions of the hornblende facies being attained only immediately adjacent to the contacts. The factors contributing to retrograde metamorphism at Big Hill are at present obscure but this should be clarified as the current work on the contact area of the whole batholith proceeds.

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Explanation to Figures

Fig. 1—Geological Map of the Big Hill Contact Area.

Fig. 2—Camera lucida drawings of spots and porphyroblasts in contact rocks, Big Hill.

- i-iii Andalusite hornfels; transitional between zone of spotted talcs and zone of biotite andalusite hornfels.
 - iv-vi Andalusite hornfels; zone of biotite andalusite hornfels.
 - vii Andalusite hornfels; transitional between zone of biotite andalusite hornfels and zone of cordierite hornfels.
 - viii Superindividual of quartz; metaquartzite, zone of cordierite hornfels.
 - ix Cordierite hornfels.
 - x Metagreywacke; zone of cordierite hornfels.
- (A andalusite, C cordierite, G graphite, SC sericite-cordierite, GI green isotropic material, GCS graphite-cordierite-sericite, GM green micaceous material, B biotite)

NOTES ON THE GEOLOGY OF THE LORNE DISTRICT, VICTORIA

By A. B. EDWARDS

[Communicated by Dr F. L. Stillwell 13 July 1961]

Editor's note: This paper has been made available for publication by Mrs A. B. Edwards. The typescript was completed by the late Dr A. B. Edwards. Dr D. E. Thomas and officers of the Mines Department of Victoria prepared the accompanying maps embracing Dr Edwards's field observations. His clay model was photographed by Mr A. A. Baker.

Introduction

The area under consideration is that part of the Otway Ranges between the sea and main water parting of the Ranges, centred on the township of Lorne (Fig. 1). It comprises especially the parishes of Lorne and Kaanglang, and part of the parish of Wongarra, in the county of Polwarth. Some reference is made to the country bordering this area (Fig. 2).

The rocks of the area are fresh water Jurassic sandstones (arkoses), mudstones and shales, with some thin, intermittent coal partings, a few inches thick, and occasional local grits and conglomerates, together with Tertiary sands, gravels and clays, mostly of uncertain age, although similar to sands and clays associated with Eocene or Paleocene coal seams at Benwerrin and Eastern View.

Interest centres chiefly in the fold-fault structures affecting the Jurassic and Tertiary sediments, and their bearing on the origin of the Otway Ranges, and in the youthful physiography of the area.

Jurassic Sediments

A petrological study of the Jurassic sediments, which predominate in the area, has been given previously (Edwards and Baker 1942). The chief additional point of petrological interest is the occurrence of occasional isolated lenticles of grit and fine conglomerate, containing fragments of relatively fresh granite, 1 to 2 cm across, and an occasional cobble (5 to 10 cm across) of fresh granite and pegmatite, together with waterworn fragments of Palaeozoic greywackes and vein quartz. These lenticles outcrop in the shore platforms S. of Queen's Park (Lorne), and in the river cliffs below the confluence of the St George R. (Fisher's Cr.) and the Cora Lynn Cr.

Similar grits and conglomerate are relatively abundant at Pt Bunbury (Apollo Bay), where the cobbles are up to 10 cm diameter, and include granite, porphyry, quartz, quartzite and shale.

Calcareous concretions are common in many of the sandstone beds, and are well exposed in the shore platforms, and the rapids of the various streams. Many are 'cannon balls', but in places adjacent concretions have 'coalesced' into irregular elongated forms. They are commonly more resistant than the enclosing rock, and project from exposed surfaces. If quarried loose they leave hollows that develop into pot holes, which appear to be a significant factor in the erosion of the hard beds.



Fig. 1—Area centred about Lorne extending from Pt Castries to the Wye R.

Lenses of massive sandstone up to 100 ft thick occur throughout the area, at various stratigraphic horizons, and without apparent continuity, forming bold bluffs and cliffs along the coast, and steep to vertical sided gorges and cliffs, waterfalls and rapids, along the streams (Fig. 1, 2).

Plant remains are common, but mostly as coalified fragments of wood. Very few identifiable remains have been observed (Medwell 1954), and no significant coal seams, apart from the seam at Skene's Cr., first described by Wilkinson (1864) and Stirling (1901).

FOLD-FAULT STRUCTURES

The almost continuous exposures along the coastline from Pt Castries to Apollo Bay, and the sections along the coastal portions of the valleys of the Erskine, St George, Sheoak, Cumberland, and other rivers, reveal a series of sub-parallel folds in the Jurassic strata, with axes trending at 75° to 85° (true) oblique to the coastline in some stretches, but elsewhere parallel to it (Fig. 1, 2). The folds are spaced at intervals of about 1 m. from syncline to adjacent anticline, and tend to be asymmetrical. This fold system appears to extend for at least 25 m. along the coast, from Pt Castries to Apollo Bay, and possibly beyond.

The best exposed fold is the **George Anticline**. The turnover of this fold is exposed in the shore platform and cliffs immediately S. of the mouth of the St George R., where the fold pitches NNE. at about 15° , and in cliffs along the valley of Sheoak R., about $\frac{1}{4}$ m. upstream from Swallow Cave. This fold, which strikes at 85° can be traced in a westerly direction for about 3 m., along the easterly trending section of the Cumberland R., until it is lost for lack of outcrops.

The most prominent fold is the **Lorne Syncline**, about 1 m. N. of the George Anticline. This syncline strikes at 75° , converging on the George Anticline westwards and is responsible for the location of Loutit Bay (Brough Smythe and Couchman 1874). It can be traced for about 4 m. WSW. of Lorne township, beyond which point it appears to die out in an area of massive flat-lying sandstone. In an ENE. direction the southerly dip of the beds forming the N. limb of the syncline continues unbroken, except for occasional small dragfolds, to beyond Pt Castries. The fold appears to continue, diminishing in intensity, in the Tertiary sediments as far as the Painkalac Cr. (Airey's R.).

Along most of its course W. of Lorne it is asymmetric. Beds in the N. limb dip at 10° to 15° SSE., whereas beds in the S. limb, adjacent to the axis, dip at 40° NNW. This dip flattens to about 20° about $\frac{1}{2}$ m. back from (SE. of) the axis. The turnover of the fold is poorly exposed in the steep valley wall of the St George R., E. of Allanvale farmhouse, along the Artist's Glen track, and it is possible that its axis may in part be a fault.

At intervals of about 1 m., and $1\frac{1}{2}$ m. respectively, N. of the Lorne Syncline, occur changes of dip indicative of an anticline and a syncline. These can be traced along their strikes by infrequent exposures, for about 2 m. (Fig. 1). Eastwards they converge, and die out in the massive, gently SSE. dipping sandstones that form the Erskine R. rapids.

Further to the N., after an interval of about 2 m., in which the beds strike at 70° to 80° , and dip 10° to 15° SE., the dips in road cuttings along the Lorne-Dean's Marsh road, and in exposures in the Little Erskine R. and Stony Cr.—on opposite sides of the road—indicate the likely presence of first an anticline, and then $\frac{1}{2}$ m. further N., another syncline, both striking at about 80° .



Fig. 2—Area S. of Fig. 1 extending from the Wye R. to Apollo Bay.

The succession of folds is interrupted at the mouth of the Cumberland R., where the beds E. of the river mouth strike at 130° , and dip at 5° - 20° NE. The abrupt change of dip and strike implies a fault striking at about 300° across the river mouth, but not exposed.

Continuing along the coast towards Mt Defiance, the strike reverts to 70° , with no break in the beds, and the dip increases to 30° - 45° NW. Between here and Mt Defiance corner, a sharp anticlinal fold, the **Mount Defiance Anticline**, is exposed in the road cutting and the sea cliffs. The beds forming the S. limb dip at 70° - 90° SE., while those in the N. limb dip at 30° - 35° NW. The steeply dipping beds are exposed in the shore platforms, and at Mt Defiance, in the road cuttings, and the turnover of the fold can be seen at two places in the cuttings and the cliffs. The beds at the turnover are somewhat crushed, so that in the shore platforms they are represented by a deep channel. E. of Mt Defiance the fold pitches at about 10° - 15° to the E. The vertical movement on this asymmetric anticline or monocline exceeds 250 ft downthrow to the SE. at Mt Defiance.

This anticline can be traced south-westwards along its strike for about 2 m., to beyond Jamieson's Cr. Exposures along the critical section of Jamieson's Cr. are poor.

SW. of Mt Defiance the coastline trends at an angle of about 30° to this anticline, and the dip declines to about 50° SE. at the mouth of Jamieson's Cr. Beyond Jamieson's Cr. the strike of the beds swings round from 70° to 40° - 55° , parallel to the coast, with the dip declining to 30° , and then to 25° at the mouth of the Wye R.

From Pt Sturt (Wye R.) to the mouth of the Kennet R. the coast is parallel to the strike of the beds, which dip about 20° seawards.

The mouth of the Kennet marks a syncline (or possibly a fault) apparently striking at about 70° , Pt Hawdon forming the S. limb of the fold, with a dip to the NE., so that the syncline pitches gently in a north-easterly direction. NE. of the mouth of the Grey R., at the head of Addis Bay, the beds are traversed by a strong NW. trending fault. Beds NE. of the fault strike at 135° , and dip NE. at about 20° ; beds SW. of the fault strike at 70° , and dip about 20° to the SE.

A second syncline, or more probably, the faulted extension of **Kennet River Syncline** outcrops between the Grey R. and Cape Patton. This syncline also strikes about 70° , and pitches gently to the NE. Its S. limb is exposed to a point 100 yds or so W. of the mouth of Carisbrook Cr., where it is truncated by another NW.-trending fault. The turnover of the syncline is exposed in road cuttings, and the strongly developed N. limb is revealed in the prominent cliff on the summit of Cape Patton, and in the NE. wall of the Carisbrook Falls (Cascades).

W. of the fault the beds strike about 70° , with a seaward dip of about 15° as far as Von Mueller Cr. These beds probably represent the N. limb of the **Kennet River or Cape Patton Syncline**, stepped SE. by the Carisbrook fault.

The Von Mueller Cr. marks a strong fault trending about $N20^{\circ}W$. W. of the fault the beds strike at 340° , and dip 15° to 25° to the SW. The dip is clearly exposed in a prominent inland cliff parallel to the coast, and in the shore platforms, which expose a minor shallow syncline pitching to the SW.

A second sub-parallel fault trends along the next major creek to the W., bringing a reversion of the strike to 70° , with a seaward dip of 15° - 20° , and this trend is maintained, with slight local variations, to the mouth of Wild Dog Cr. Apollo Bay appears to mark another major syncline, comparable with Loutit Bay (Wil-

kinson 1865, Brough Smyth and Couchman 1874, Stirling 1901). This **Apollo Bay Syncline** strikes at 70° - 75° , and pitches gently in this direction. Pt Bunbury, the S. arm of the bay comprises beds striking at 70° - 90° , and dipping at 8° - 18° to the N. and NE., and this attitude of dip is maintained at Pt Hayley, but an anticline may intervene near the mouth of the Barrum R. (Murray 1887).

On the N. side of the syncline, about $\frac{1}{4}$ m. N. of the mouth of Skene's Cr., is a strong monoclinical structure, comparable with the structure at Mt Defiance, and which may be called the **Skene's Creek Monocline**. This structure consists of a belt of thin bedded shales and arkoses, up to $\frac{1}{2}$ m. wide, striking at 50° - 70° , and dipping at 70° - 80° SE. It has been traced by V. R. Stirling (1901) over a strike length of more than 3 m., from Brown's Cr. to the mouth of Wild Dog Cr. (Fig. 2). The steep dips are well exposed in the successive valley walls, and particularly well in the almost continuous road cuttings of the Tanbryn-Skene's Cr. road. The 3 ft coal seam on Skene's Cr. occurs within this steeply dipping zone.

Southwards from the steeply dipping zone the dip flattens progressively to about 15° in the shore platforms. To the N. also the dips decline to about 30° SE., and the shales are then replaced by thick beds of sandstone which dip at 0° - 20° NW., the dip increasing to the NW., so that there is here either an anticline, or a change in dip due to faulting.

A further zone of beds dipping steeply to the SE. (55° - 65°) was found by Stirling (1901) a short distance up the Wild Dog Cr. This may be a second monocline or a faulted extension of the Skene's Creek Monocline.

ORIGIN OF THE FOLDS

The features of these folds are:—

- (a) their more or less parallel strikes,
- (b) their relative continuity, remarkable for an area of Jurassic rocks in Victoria,
- (c) their frequent asymmetry, with steep dips on their southern limbs,
- (d) their tendency to die out as they approach thick bodies of massive sandstone.

They appear to be the product of compressional stresses acting on sediments of varying competence.

The fold structures have influenced the form of the coastline, which trends parallel to their strike. In the vicinity of Mt Defiance the coast coincides with a steep limb of a very asymmetrical anticline (or monocline); and the linear form of the coastline as a whole suggests that the SE. margin of the Otway Ranges is terminated either by a major monocline or fault, to which these folds are subsidiary, or by a series of such structures in *en echelon* arrangement, all with a downthrow to the SE., with successive faults or folds or monoclines stepping to the SE., if traversed in a south-westerly direction.

The folds may indicate a period of orogenic compression during the late Cainozoic, if they extend to the Otways as a whole. In this regard it may be noted here that a steeply dipping monoclinical structure, akin to the Skene's Creek Monocline but throwing down to the N., is exposed in the Laver's Hill-Princeton road about 1 m. W. of Crowes railway siding. If they prove to be restricted to the coastal belt, then a more likely explanation is that they are due to the down-warping that marks the SE. limit of the Otway Ranges. If one pictures the development of a simple steeply dipping monocline in stratified rocks, without any of the strata

slipping over one another, the beds on the convex side of the flexure will be in tension, and can be lengthened only by fractures, while the beds on the concave side, must be in compression, and can be shortened only by shear thrusts (Hills 1940A), as may be seen in the Yallourn North Open Cut. In a system of inter-bedded competent and incompetent beds, the stresses set up by a strong monoclinical warp are likely to be relieved, in part at least, by slipping of the more competent strata over one another, with the development of folds equivalent to drag folds in the less competent strata between them. In a series of lensing formation such 'drag folds' would tend to die out on approaching a lens of competent strata; and some deflection of the strike of the fold, away from parallelism to the monocline, might be expected from a fortuitously irregular distribution of the lenses of competent strata.

Shallow minor synclinal dragfolds subsidiary to the larger 'drag folds' occur in the shore platforms SW. of Big Hill Cr., SW. of Pt Grey, and SW. of Von Mueller Cr.

FAULTS

Numerous dip faults, trending more or less normal to the coastline intersect or displace the fold-fault structures. These faults are either visible in the shore platforms or are inferred from abrupt changes of strike that coincide with notably linear valleys, like Brown's Cr., E. of Skene's Cr.

Most of the exposed dip faults strike NW. to N. displacing the folded strata horizontally, and with a tendency for the SW. block to move SE.

The majority of the exposed faults have relatively small displacements, and none is comparable with the major scarp-producing faults that bound individual fault blocks in S. Gippsland.

Tertiary Sediments

Gravels, sands and clays, with occasional bands of 'ironstone' or ferruginous sandstone of indefinite Tertiary age outcrop at a number of points in the area (Fig. 1). Their presence is commonly indicated by white quartz sand, or by numerous coarse grains of quartz in the soil, a feature not shown by the soils on the Jurassic rocks.

The best exposure of these rocks is in a quarry about 150 yds W. of the pressure reservoir at the head of William St, Lorne, on the road to Erskine Falls. A thickness of about 30 ft of gravels, with intercalated clay bands, is exposed in section in the quarry. The gravels are bedded, with some current bedding. They strike at 100° , and dip at 15° S. A further good exposure is in the quarry on the E. side of the Dean's Marsh-Lorne road, between Benwerrin and the turn-in road to the Benwerrin Colliery. Other good exposures are in shallow borrow pits on the spur above N. Lorne, and along the ridge SW. of Big Hill Cr.

These gravels are composed predominantly of white quartz, with some bluish to black quartz and pebbles of quartzite, some of which carry quartz veins. The larger pebbles, in particular, are well waterworn, as is much of the finer-grained quartz, but in some of the gravel exposures the quartz grains are angular, but surprisingly well sized, pointing to derivation from a weathered granitic source without undue wear in transport.

The gravels and sands are more strongly developed along the coastal margins than on the ridges in the interior of the Otway Ranges, or along the divide, except

to the N. of Benwerrin and in the vicinity of the Benwerrin Colliery. They occur, moreover, at various levels. Some cap ridges and hill tops, as along the road to Teddy's Lookout (430 ft), and near the summit of Mt St George (650 ft), but others occur well below the summits of adjacent hills composed of Jurassic rocks, as at N. Lorne, and along the track to Allanvale, so that they appear to fill depressions in an older post-Jurassic surface, or have been affected by the relatively recent earth movements.

At Benwerrin Coal Mine, 300 ft below the summits of the adjacent hills composed of Jurassic sediments, they owe their preservation to faulting. Whitelaw (1900) has reported the presence of marine fossils in sands at this locality (the former Great Western Colliery).

At Cape Patton comparable sands are exposed in section along a prominent N.-S. cliff, a short distance inland from the coast, at a height of 580 ft above sea-level. These sands are at a slightly lower elevation than the Jurassic sediments immediately to the N. and S. of them, and lie adjacent to the axis of the Cape Patton syncline in the Jurassic rocks. The stratification of the Tertiary sediments is poorly exposed, but they appear to have the same general dip as the underlying Jurassic beds. Fossils of Eocene age are reported to occur in these beds (Stirling 1901, p. 7; Hall 1909, pp. 103-104), but no fossils were found during the present examination.

Similar, but non-fossiliferous, sands form a capping to the Eagle's Nest cliff, at 360 ft above sea-level, E. of Skene's Cr., and Pt Bunbury, at 60 ft above sea-level (Stirling 1901).

EASTERN VIEW COAL MEASURES

Tertiary sediments of Paleocene or Eocene age (Raggatt and Crespin 1952, Cookson 1954) are exposed at Eastern View along the coast and cliffs, and in the creek sections from about Spout Cr. (E. of Pt Castries), eastwards as far as Painkalac Cr. (Airey's R.). Their contact with the Jurassic sediments is not exposed on the beach, but the uppermost Jurassic sediments exposed are heavily impregnated with limonite. The strike and dip of the Tertiary beds are close to those of the Jurassic sediments, indicating that both formations have been affected by the same earth movements. The contact, however, must be unconformable.

About 50 ft above the base of the Tertiary sediments, as exposed on the beach, is the lowest of a series of 5 thin seams of brown coal, each from 2 to 3 ft thick. They strike 45° and dip at 20° SE. Analyses have been made of 3 of these seams, with the results shown in Table 1.

TABLE 1
Proximate Analyses of Eastern View Coal Seams

	1	2	3
Moisture, as received	5.12	6.57	15.11
Volatile matter	14.13	17.14	33.93
Fixed carbon	12.15	14.98	35.34
Ash	68.60	61.31	15.74
	100.0	100.0	100.0

1 Lowest seam outcropping on beach, Eastern View

2 Third lowest seam outcropping on beach, Eastern View

3 Fourth lowest seam outcropping on beach, Eastern View.

Overlying the coal seams are two brown ironstained beds of sandy siderite, each about 2-3 ft thick. These consist of fragments of felspar (kaolinized), quartz, chert, granophyre and shaly rock in a matrix of about 50% siderite. The siderite forms encrustations about individual mineral grains and fills interstices.

Inland the extension of these coal seams is masked by sand dunes, but Krause (1874) has suggested that they may represent the continuation of the two seams of brown coal exposed in workings on the Coalmine Cr. (the Stony Cr. of Krause's report). These workings have collapsed but, according to Krause, the upper seam, which was 5 ft thick, was 50 ft above the lower seam, which was 15 ft thick, and was about 50 ft above the Jurassic surface. A thin leaf bed occurred 20 ft above the top of the lower seam. The upper part of the 15 ft seam, as exposed in the shaft, consisted of shaly brown coal overlying a central portion of more compact nature. Below this the coal contained intercalations of sandy shale. The contact of the Tertiary sands and the underlying Jurassic was exposed further upstream.

At present a seam of somewhat sandy brown coal about 5 ft thick, with clay partings, is exposed on the NE. side of Coalmine Cr., about 100 yds upstream from the Ocean Road, with a 2 ft thick bed of ligneous clay about 20 ft above it. Both coal seam and ligneous clay strike at about 80° and dip 30° to the S., as do the Jurassic strata a short distance further upstream. The contact between the Tertiary sediments and the Jurassic is partly hidden by land slips.

Overlying the coal seams is a considerable thickness of whitish sands, clays and ferruginous sandstones, exposed by landslides in the sides of Coalmine Cr., and in the cliffed escarpment behind the Eastern View Hotel. These beds all dip at about 30° S.

A further seam of brown coal, several feet thick, outcrops on the shore about 250 yds SW. of the mouth of Mogg's Cr. (about opposite 'Blue Waters', the third house W. of the Creck). This seam overlies a bed of ferruginous sandstone, which outcrops at normal low tides, and dips seaward. The coal seam is exposed only at exceptional low tides, or when sand has been scoured from this section of the coast. The coal burns readily when air-dried.

The microflora of each of these several coal seams are practically identical and are characterized by the rare pollen *Triorities edwardsii* (Cookson 1954), indicative of Paleocene or early Eocene age.

Raggatt and Crespin (1952) have divided these sediments into the Eastern View Coal Measures, extending to the top of the fifth coal seam exposed on the beach at Eastern View, and the Boonah Sandstone comprising the sands and clays, extending from Eastern View as far as Mogg's Cr. In view of the discovery of a sixth seam, with a more or less identical microflora, in the so-called Boonah Sandstone, it seems desirable to discard this subdivision and include all the sediments between Spot Cr. and Mogg's Cr. as members of the Eastern View Coal Measures. Raggatt (pers. comm.) suspects the presence of an anticline between this coal seam and that at Eastern View but I cannot find this anticline and have noted only a uniformity of dips and strikes on this section of the coast.

At Mogg's Cr. there is a sudden change from freshwater to marine sediments, with no very pronounced change in strike or dip. Raggatt and Crespin (1955, p. 108) state that these beds 'dip at 30° on a bearing of 350° ', but show them dipping at 30° on a bearing of approximately 145° on their map (Fig. 1). The map is more nearly correct and the strike of the beds is about 80° .

Eastwards from Mogg's Cr. as far as Fairhaven, *Cyclammina*-bearing grey silts

and sands, spotted with yellow copiapite are exposed almost continuously in the road cuttings. E. of Fairhaven they pass below reddish clays, which are exposed in the cutting leading to the bridge over Painkalac Cr. (Airey's R.).

In the shore platform between Mogg's Cr. and Fairhaven there is an extensive outcrop of blackish-brown ligneous clay. The clay strikes parallel to the coast, and dips seawards at about 15° . It is only exposed at very low tides and after periods of sand scour. The ligneous clay, which is interleaved with ferruginous sandstones or silts, is studded with nodules and rods of marcasite. The rods are up to 10 mm long and 1 mm diameter, and are pseudomorphous after fragments of wood. The nodules are commonly casts after marine fossils, including *Cyclammmina*, and unreplaced remains of *Cyclammmina* are also preserved. Freshly broken surfaces of the clay show a faint criss-cross pattern of indeterminate origin.

The outcrop of this ligneous clay extends for about 250 yds, from opposite the highest point along this section of the coast to about opposite the first house at the SW. end of Fairhaven hamlet. The clay matches in all points the ligneous clay outcropping in the case of the cliffs immediately SW. of Anglesea (except that in the outcropping ligneous clay at Anglesea the marcasite bodies are converted to limonite) and the ligneous clay at the lower half of the cliffs at Demon's Bluff.

From its situation and its dip it is clear that this ligneous clay is the same formation that outcrops, severely weathered, in the road cuttings, where the marcasite of the ligneous clay is altered to copiapite and limonite.

This ligneous clay represents, therefore, the Anglesea Siltstone Member of Raggatt and Crespin's (1952) Demon's Bluff Formation, of which they state—'a complete section of the Formation is exposed at only one place—between Mogg's Creek and Airey's River. Here, because of its uniform lithology and colour, the Members . . . cannot be identified'.

If this is correct, then the Addiscot Greywacke Member and the Anglesea Siltstone Member are one and the same formation, the Addiscot Greywacke being simply the weathered and oxidized outcrop of the Anglesea Siltstone. The association at Demon's Bluff appears to bear the same interpretation, so that the term Addiscot Greywacke Member should be discarded.

At the E. end of its extent the clay appears to pass beneath a platform eroded in compacted dune sands, with occasional thin beds of conglomerate, which extends almost to the first outcrop of limestone at Airey's Inlet.

The broad gap cut by the Painkalac Cr. masks the relationship between Anglesea Siltstone and the highly fossiliferous marine limestones, and pyroclastics (Angahook Member) that form the cliffs extending E. and NE. from Airey's Inlet. Just W. of Painkalac Cr. they strike at 65° - 70° and dip at 5° - 10° SE., whereas the limestones at Airey's Inlet dip about 5° - 10° NW., so that the Painkalac Cr. appears to occupy a shallow syncline, and the sands and ligneous clays appear to pass beneath the limestones and the pyroclastics.

The olivine-basalt at Split Pt (Airey's Inlet) forms the neck of an old volcano, and is surrounded by, and intrusive into, pyroclastics which comprise beds of varying thickness of ash, lapilli and agglomerate, severely weathered, but preserving much of their original texture. Ejected blocks of olivine-basalt, up to 3 ft across, occur at frequent intervals in most of the pyroclastic beds, which have a general northerly dip, and are cut in one or two places by dykes or 'sills' of basalt. Many of the ejected blocks are still glassy, with a ropy texture. Associated with them in places are smaller blocks and fragments of thin-bedded to finely current-bedded

siltstones, derived from deeper-lying Tertiary sedimentary formations. They are petrographically distinct from the Jurassic arkoses, and so are presumed to be derived from the Anglesea Siltstone, or from Tertiary sediments of comparable age.

The limestones overlie the pyroclastics in the cliff sections, the two being separated by an impersistent bed of conglomerate, made up of waterworn basalt boulders, capped by 1-6 ft of horizontally bedded vari-coloured sands, which are iron-stained, and carry a proportion of ilmenite. In places they appear ligneous.

Near the major rock stone stack forming Split Pt the limestones come down to the shore platform, giving the platform a distinctive rough to jagged surface, as a result of solution benching processes, but a narrow width of the pyroclastic beds exposed N. and E. of the columnar basalt forming the base of the main stack establishes its plug form.

The limestone sections of the cliff are marked by conical sink-holes, largely filled with ferruginous clays.

BENWERRIN COAL MEASURES

Coal seams of Paleocene to early Eocene age, characterized by a *Triorites edwardsii* microflora (Cookson 1954), occur intercalated with sands and clays in a down-faulted block about 2 m. N. of Benwerrin (Fig. 1). The Tertiary beds are up to 300 ft thick, and cover an area of about 150 acres. Their base is 300 to 350 ft below the Jurassic sediments capping the surrounding hills, and they lie directly on the Jurassic sediments.

The coal seams outcropped in the bed of Box Cr., a tributary of Grassy Cr., which crosses the Tertiary formation in a general southerly direction, and a series of 10 bores put down by the Victorian Mines Department in 1942, reveal that over an area of about 20 acres the sands and clays contain from 1 to 3 seams of coal (Kenny 1947). The upper 2 seams are from 6 in. to 3 ft thick; the lowest seam is 7 to 9 ft thick, and underlies an area of about 10 acres, in which it dips at 1 in 11 to the S. It has been worked intermittently on the N. side of this area, firstly by the Great Western Colliery, which between 1901 and 1903 produced 6,850 tons of coal, and then from 1943 to 1948 by the Benwerrin Colliery, which produced a further 4,544 tons. Reserves were estimated in 1942 as 75,000 tons.

Whitelaw (1900) reports the occurrence of marine fossils, regarded by Denant as Eocene, in the sediments cut in a shaft sunk about 5 to 10 chains NW. of the workings of the Great Western Colliery. This shaft passed through 112 ft of sands and clays overlying a 9 ft thick coal seam, which rested almost directly on the Jurassic strata. No further marine fossils were found in the mine workings, which entered the seam by edits, where it was under only shallow cover.

The workings of the Great Western Colliery are inaccessible, but three new entrances to the lowest or main seam have been made since 1943 in the Benwerrin Colliery. The most south-westerly of these new workings consisted of 3 bords driven on level course, and 2 cross bords on the dip, with 40 ft pillars, but the roadways collapsed before the pillars were extracted. In these workings the main seam is 8 ft thick. The upper 18 in. contains numerous thin lenses of sandy clay, intercalated with lenses of vitrain (logs), and was not mined. Above this is 4 ft of white clay, with occasional lenses of vitrain, showing growth rings, and clearly derived from isolated logs of wood, compacted about 50% of their original thickness. Above this is a second seam, only 12 in. thick. The dip of the seams was to

the NW. at about 1 in 20, and the coal showed a closely spaced cleat trending a little E. of N.

The second entrance was made north-westwards, from the W. bank of the S.-trending branch of the creek, between its junction with the E.-trending branch and the old workings of the Great Western Colliery. In 1948 it had entered about 100 ft, and 3 bords had been established on the dip, with 2 cross bords on level course, separated by 40 ft pillars. Here the main seam was 6 ft thick, with a distinct cleat striking E. of N., and a dip of about 1 in 20 to the NW. The area of available coal was limited, however, by the proximity of the old workings, and a bore 5 chains to the NW. showed only 18 in. of coal, although Whitelaw (1900) records 9 ft of coal in a single seam in the old shaft several chains further NW.

The third entrance was an incline on the dip trending parallel to the inclined tramway to the bunkers, on the S. side of the creek, at the junction of the two branches. The seam here was 7 ft thick, and dipped to the S., so that either the seam is faulted along the easterly trending branch of Box Cr., or it is folded into a gentle anticline pitching flatly to the W.

The Benwerrin coal seams are black, with a brown streak, and correspond to the *Glanzbraunkohle* of German classifications. The main seam, as exposed in the various workings of the Benwerrin Colliery, consists largely of alternating bands, up to 12 in. thick of bright and dull coal, corresponding more or less to clarain and durain. Two fusain-rich bands, each about 2 in. thick, occur in the central part of the seam, and 'crusts' of fusain about 0.25 in. thick occur about cores of

TABLE 2
Analyses of Benwerrin Coal Seams

	1	2	3	4	5	6	7	8
Moisture	31.68	19.36	29.85	30.4	33.4	—	—	—
Volatile Matter	26.73	16.81	30.05	27.3	26.7	—	—	—
Fixed Carbon	35.59	17.79	35.55	33.2	28.2	—	—	—
Ash	6.00	46.04	4.55	9.1	1.7	4.12	4.82	—
Dry, ash-free basis:								
Volatile Matter	42.9	48.6	45.8	45.1	41.2	44.2	46.3	36.4
Carbon	—	—	73.70	73.7	72.0	—	—	—
Hydrogen	—	—	4.76	4.75	4.65	—	—	—
Nitrogen	—	—	1.02	1.0	1.05	—	—	—
Sulphur	—	—	—	0.35	0.5	—	—	—
Oxygen	—	—	20.33	20.2	21.8	—	—	—
Calorific Value (B.t.u. per No.)	11600	—	11930	11540	12535	—	—	—

1 No. 1 or Top Seam (Kenny *Min. Geol. Jour.* 3; 1, 1947: 12)

2 No. 2 or Middle Seam (Kenny *Min. Geol. Jour.* 3; 1, 1947: 12)

3 No. 3 or Main Seam, NE. workings, Benwerrin Colliery, run-of-mine (Edwards *Proc. Aus. I.M.M.* 140, 1945: 210)

4 No. 3 or Main Seam, NW. workings, Benwerrin Colliery (Brown *Min. Geol. Jour.* 3; 4, 1948: 10)

5 No. 3 or Main Seam, S. workings, Benwerrin Colliery (F.F. Field, Mines Dept, Victoria, 1950)

6 Vitrain, composite sample from Main Seam (Edwards *Proc. Aus. I.M.M.* 140, 1945: 242)

7 Dull coal, or durain, from Main Seam (Edwards *Proc. Aus. I.M.M.* 140, 1945: 242)

8 Fusain, from Main Seam (Edwards *Proc. Aus. I.M.M.* 140, 1945: 242)

vitrain, 0.5 in. thick, in the top 12 in. of the seam. Vitrain, derived from logs and branches of wood, still showing growth rings, forms lenses throughout the seam.

Analyses of the coal are shown in Table 2. Ranked in terms of vitrain analyses, this coal can be classed as sub-bituminous, and intermediate in rank between the Triassic Leigh Creek coals of South Australia, and the Permian Collie coals of Western Australia (Edwards 1950).

Physiography

The area is one of youthful physiography, which is most apparent in the form of the streams. Of the rivers, only 4—the Kennet, Wye, St George and Erskine—have valley tracts; and the longest of these, that of the Wye, is less than 1 m. long.

The beds of massive arkose have given rise to rapids where streams cross them on the dip slope. The rapids on the Erskine below its confluence with the Little Erskine are about 50 yds wide and 400 yds long, and rapids extend up the Little Erskine for about $\frac{1}{2}$ m. Rapids up to 30 yds wide and 300 yds long occur on the St George R. below its confluence with the Cora Lynn Cr., and the Cora Lynn Cr. itself, cascades down a series of steep rapids near the head of the Cora Lynn bridge track, as does the Carisbrook Cr. about $\frac{1}{4}$ m. above its mouth. Lesser rapids occur along the Sheoak and Cumberland R., and most other streams flowing over the Jurassic rocks.

Where massive arkose beds are horizontal, or dip upstream, headward erosion has given rise to waterfalls with vertical drops of from 20 to 100 ft, and short steep-sided to vertical walled gorges downstream, as on the Sheoak and St George R. Such features are common to the area, and to the Otway Ranges generally. The arkose beds constitute a series of temporary base levels, and upstream from such a waterfall it is not uncommon for a valley to widen, and possess a small bouldery flood plain.

An outcome of the rapid down-cutting of the streams, combined with the occurrence of lensiform beds of massive arkose, 50 to 200 ft thick, at various stratigraphic horizons, is the development of meanders set in deep cliffed amphitheatres, where a stream has been superimposed on the massive arkose beds, and has cut its way round, rather than through, the lens of arkose. A beautiful example, presenting a combination of gorge, waterfall, meanders, cliffed amphitheatre, temporary flood plain and imminent domestic piracy is provided by the St George R. (Fisher's Cr.) immediately upstream from its confluence with the Cora Lynn Cr., about $\frac{1}{2}$ m. above Allanvale bridge. Pl. X shows these features modelled approximately to scale in clay.

Upstream from the junction of the two streams the St George flows through a short gorge with nearly vertical sides, formed by the headward erosion of the Phantom Falls, which have a drop of about 60 ft. Above the falls the stream flows on the surface of a massive arkose bed, meandering in a bouldery flood plain that is bounded on the S. by a cliffed amphitheatre with walls 100 to 200 ft high, and a radius of about 200 yds. About 1 m. further upstream the St George R. (Fisher's Cr.) approaches within $\frac{1}{4}$ m. of the Cora Lynn Cr. At this point the Cora Lynn Cr. lies about 100 ft below the outer (convex) side of a large meander of the St. George R. through its temporary flood plain. The divide between the two streams is about 100 ft E. of the St George R., and less than 20 ft above its normal level, so that a severe flood or cloudburst in the upper reaches of the St George could cause it to break through to the Cora Lynn at this point.

The straight and deeper, uninterrupted SE.-trending course of the Cora Lynn Cr. suggests that it flows along a fault, but there is no sign of the fault below its confluence with the St George R., where the extensive rapids give place to a sharp bend to the E., fronted on the S. by vertical cliffs, marks a stage in the development of another cliffed amphitheatre.

The cliffed bends of the Erskine R., downstream from the Erskine Falls, mark a more advanced stage in the development of a cliffed amphitheatre. Below Allanvale bridge the St George shows a further development of pronounced meanders in cliffed amphitheatres.

The gorge extending upstream from the mouth of the Cumberland R. shows sharp bends with vertical walls. At its mouth it appears to follow the course of a fault, but upstream it appears to have developed by headward erosion through massive flat-lying arkose beds. The vertical sides of the gorge are due largely to the undercutting of the massive arkose in a bed or beds of mudstone at the base of the arkose. The gorges, waterfall, rapids and bends of the Sheoak R., as far upstream as the Swallow Cave, are mainly formed in response to headward erosion from a sea-cliff.

DRY VALLEYS

Dry valleys occur at several places, and are due to varied causes. A truncated dry valley with gently sloping walls extends from the valley of the Cumberland R. in an easterly direction on the N. side of the two hills known as the Brothers, encountering the coastal cliffs some 30 ft above sea level, a little to the W. of the Sheoak Cr. mouth. Hall (1909, p. 97) suggests that this was the original mouth of the Cumberland, which now flows past the cut-off end of its old bed, about 100 ft below it. Presumably this is the result of piracy by a smaller stream cutting back from the coastal cliffs, possibly along a fault.

The high sea cliffs immediately W. of the mouth of Big Hill Cr. mask a deep gorge-like hanging valley whose headward end has been destroyed by marine erosion. The landward wall of this dry valley is a vertical cliff more than 100 ft high. On the seaward side a narrow razorback, with vertical sides, separates it from the sea. The 'mouth' of the valley is about 60 ft above sea level. It must once have been occupied by a stream at least as large as Big Hill Cr., and its preservation as a hanging valley points to a considerable recession of the sea cliffs along this part of the coast.

Three peculiar dry valleys occur to the SW. of Phantom Falls. The track from Phantom Falls to Henderson's Falls passes through two of them, the more 'dramatic' of which is known as the 'Canyon'. The third valley is about 200 yds S. of the Canyon and parallel to it.

The Canyon is about 200 yds long, and trends across a ridge between two streams, at right angles to the axis of the ridge and the streams. At its E. end it is a cleft about 30 ft wide with vertical walls 30 ft high, and it widens and shallows towards the W. end. The floor consists of huge angular blocks of arkose piled irregularly on each other, so that it appears to be a collapsed cave. A remnant of the roof remains at the E. end. Caves on such a scale are unusual in the Jurassic rocks, but one such cave occurs some distance above sea level at Cape Patton, and a collapsed cave (The Devil's Punch Bowl) is known on the S. coast of the San Remo Peninsula (Edwards 1942). The Swallow Caves, above the Sheoak Falls, may represent similar caves truncated by headward erosion of the Sheoak

Falls and rapids, but may be due chiefly to undercutting by the river in flood. Small sea caves occur in the cliffs W. of the Cumberland R. and at the foot of Big Hill.

The dry valley just S. of the Canyon is about twice as wide, and somewhat deeper, with similar vertical walls and a floor composed of angular blocks.

The third of these dry valleys cuts across the next ridge to the SW. Its E. end is high above the present streams, but its W. end leads down to Henderson's Cr. The track follows down the centre of it, between steep to vertical walls. This valley is due, in part at least, to erosion by running water.

It is suggested that these valleys originated as caves through the solution of calcite from zones of highly calcareous arkose, such as occurs in parts of Gippsland (Edwards and Baker 1942, p. 205).

DRAINAGE PATTERN

Two directions dominate the drainage pattern—a SE. direction, approximately normal to the divide of the Otways, and commonly following a dip slope; and an E. direction (about 80°), approximately parallel to the fold axes, tending to develop where massive arkose is encountered. Many streams show both trends. Easterly trends are less in evidence W. of Cape Patton than E. of it.

Skene's Cr., Wild Dog Cr. and the Barrum R. flow almost due S. in their upper courses.

COASTLINE

The coastline from Pt Castries to Apollo Bay falls into two sections. As far as Cape Patton it consists of cliffs up to 300 ft high with a steeply sloping hinterland, fronted by flat rock platforms that rise abruptly above low tide-level, with occasional interruptions by stretches of sandy beach, at the mouths of the bigger streams. The major sections of beach coincide with synclinal structures.

From Cape Patton (actually Sugarloaf Hill) to Apollo Bay, there is a narrow coastal plain rising 20 to 40 ft above sea-level, backed by steep hills, and marking a relatively recent emergence. Traces of this coastal plain can be detected at Pt Hawdon, Pt Sturt, Pt Grey, and possibly at Mogg's Cr., on the Pt Castries side of Cape Patton. The seaward edge of the coastal plain is generally marked by low cliffs, and rock platforms similar to those nearer Lorne, and occasionally by sand dunes.

The general trend of the coastline is SW., in a series of nearly straight lines, stepped out *en echelon* to the SE. going south-westwards. These steps, of which the most marked are at Loutit Bay (Lorne) and Apollo Bay, coincide with synclinal structures.

For most of its length the rocks dip seawards, and the shoreline parallels the strike of the beds, but for short stretches between the Erskine and St George R., between Pt Hawdon (Kennet R.) and Carisbrook Cr., and also at Pt Bunbury, the dip is inland.

NE. of Pt Castries, where the Jurassic rocks give place to soft Tertiary sediments the cliffs are weathered back and tend to be fronted with sand dunes and long stretches of beach, broken only by the harder rocks of Split Pt at Airey's Inlet, and by lesser outcrops of ferruginous sandstones at about low tide level.

The rock platforms W. of Pt Castries have been described in detail elsewhere (Edwards 1951; Jutson 1949, 1954). They are interrupted by channels along major joints, faults and crush zones, and are narrowest and least regular in the

nearly vertical beds at the foot of Mt Defiance, where the cliffs behind them are highest.

The cliffs and platforms are subjected to active marine erosion, and the smaller streams have difficulty in keeping pace with the erosion, so that they tend to enter the sea by steep cascades.

Formation of the Otways

Two views have been proposed as to the origin of the Otway Ranges. Krause (1874) pictured the Otways as an island in the Tertiary seas, the Tertiary sediments being deposited around its margins. This view has the support of Hall (1909, p. 99), Coulson (1938) and Thomas and Baragwanath (1949, p. 32). The alternative view, proposed by Hills (1940B, p. 267) is that the Otway Ranges were domed up by fault and fold movements late in the Cainozoic, and that their original Tertiary cover has been stripped from them.

Evidence in support of the second view is to be found in the rank of the Benwerrin coals, which are intermediate in rank between the Triassic Leigh Cr. coals of South Australia and the Permian Collie coals of Western Australia (Edwards 1950). Metamorphism due to tectonic and igneous agencies can be excluded, as cause for its relatively high rank, so that the Benwerrin coal must at one time have been buried beneath a considerable cover, because, under such conditions, rank is largely a reflection of depth of burial.

The Benwerrin coal is of as high rank as the brown coal cut in the Wurruck Wurruck No. 1 Bore, at a depth of 2560-2714 ft, and in terms of carbon content is either equal, or somewhat lower in rank than the brown coal at 3610-3633 ft in Bengworden South No. 2 Bore. The comparison is rendered difficult by the high sulphur content of the Bengworden coal—possibly organic sulphur (Edwards 1945, p. 224). This suggests, therefore, that the Benwerrin coal seams were originally buried beneath a cover of not less than 2500 ft of Tertiary sediments, and possibly as much as 3500 ft. The smaller figure is comparable with the total thickness of freshwater and marine sediments extending from the base of the Tertiary at Eastern View to the top of the sequence exposed at Torquay, as computed by Raggatt and Crespín (1952). It may be noted, moreover, that marine fossils occur in the sands above the Benwerrin seam (Whitelaw 1900), which provides proof of some degree of subsidence after the coal was deposited.

Some check on this estimate can be made by plotting the moisture contents of the coal seams cut in the Notown Bore, New Zealand (Wellman 1950) against their depth of occurrence, and the moisture content of the Yallourn seam, against an assumed original estimated cover of 600 ft thickness (Fig. 3). If a curve is drawn through the three points obtained, the approximate original thickness of cover over the Benwerrin seam can be estimated from it. According to the moisture contents of the several reliable analyses quoted in Table 2, it was originally buried to a depth of 2200-2500 ft. An error of ± 500 ft in the thickness of the original overburden of the Yallourn seam would not affect the estimate significantly.

The absence of igneous rocks capable of metamorphosing the coal is a feature of the Otway Ranges distinguishing them from the South Gippsland Highlands. To the E. at Airey's Inlet olivine-basalt volcanic necks and pyroclastics intrude and overlie Eocene sediments (Anglesea Siltstones and Eastern View Coal Measures, or their equivalents), and are unconformably overlain by thin beds of

conglomerate and sandstone and by Janjukian limestones (Point Addis Member of Raggatt and Crespin 1952).

At Gellibrand and Kawarren, on the opposite side of the Otway Ranges, there are further outcrops of olivine-basalt, as horizontal flows resting on the Jurassic surface, and as necks and dykes which have indurated the overlying Tertiary sands and clays that they intruded. Ligneous clays, upwards of 115 ft thick, containing fossil shells and pyrite (Anglesea Siltstones?) and thin seams of brown coal occur low in the Tertiary sequence, 'possibly below the horizon of the basalt flow in Love's Creek, although the latter rests directly on Jurassic strata' (Kenny 1938, p. 76). Overlying the ligneous clays, and separated from them by 80 to 90 ft of sands and

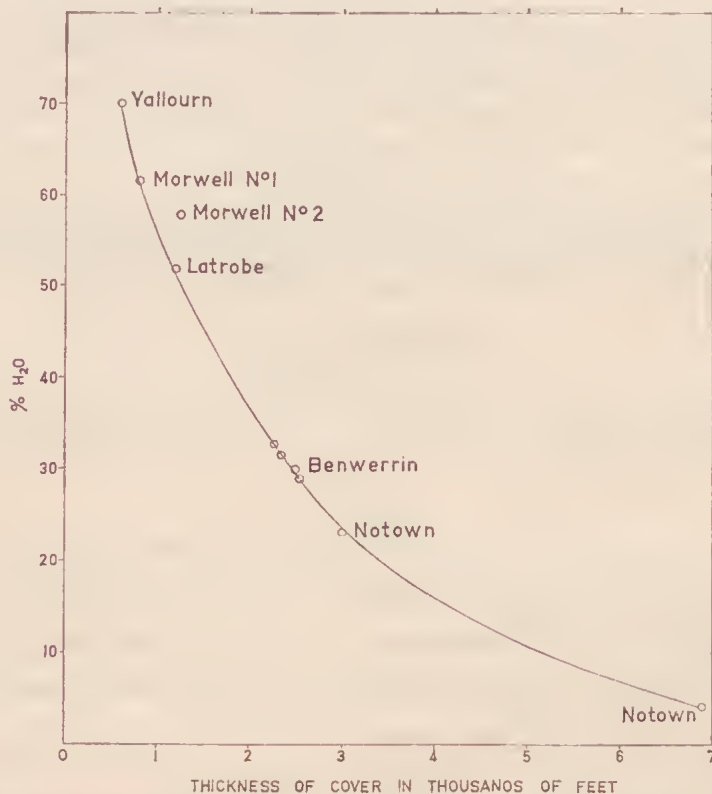


Fig. 3—Relation of moisture contents of coal seams to depth of burial when tectonic and igneous agencies are absent.

clays, is the horizontally bedded Kawarren Limestone, described as typically Janjukian by Chapman (Kenny 1938), with a fossil fauna practically identical with that of the limestone at Airey's Inlet (O. P. Singleton: pers. comm.).

In view of these basaltic occurrences, the absence of basaltic plugs or dykes from the Otway Ranges may mean that the region was not subjected to faulting or related earth movements during the period of volcanic activity.

The physiographic evidence is proof that the Otways were elevated in late Tertiary time, probably the Pliocene, by the processes of faulting and folding that

determined the shape of the present coastline. The Tertiary sediments as a whole were warped and folded by these movements, but where adjacent to the Jurassic show only a slight degree of unconformity, so that little or no folding or tilting could have occurred in the Jurassic rocks before the Eocene.

The soft and often unconsolidated nature of the Tertiary sediments would render them liable to rapid removal when subjected to vigorous erosion following the Pliocene elevation. Where Tertiary sediments are preserved within the Jurassic areas they occur in sheltered positions which they owe largely to the effects of the faulting.

The narrow coastal plain extending from Apollo Bay towards Cape Patton points to a further minor, possibly Pleistocene, emergence, which would have rejuvenated the still vigorous erosion resulting from the major uplift.

In the absence of reliable evidence of earlier tectonic movements it can be assumed that any metamorphism of the Benwerrin coal by tectonic forces would have occurred during the Pliocene, but as is apparent in the Morwell district, and particularly in the Latrobe seam, pressure developed during monoclinical folding sufficient to cause considerable overthrusting of the coal seam did not raise it to anything like the rank of the Benwerrin seams.

The forces operating in the Otways were no greater than those in South Gippsland, and probably were weaker. The rank of the Benwerrin coals must be attributed, therefore, to overburden pressure with all that this implies.

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Explanation of Plate

PLATE X

Relief model of the area around the confluence of St George R. (R) and the Cora Lynn Cr. (C). Phantom Falls (P) occur at the head of a gorge (G). A cliffed amphitheatre (A) and a flood plain (F) with meanders occur above the falls. A low divide (D) occurs between the St George R. and the Cora Lynn Cr. Horizontal scale approximately 1 in. = 30 chains, vertical scale 1 in. = 100 ft.



THE PALAEOONTOLOGY AND STRATIGRAPHY OF THE SILURO-DEVONIAN SEDIMENTS OF THE TYERS AREA, GIPPSLAND, VICTORIA

By G. M. PHILIP

[Read 8 December 1960]

Abstract

A discussion of the structure, stratigraphical subdivisions, lithologies and fauna of the Siluro-Devonian sediments of the Tyers area is given. Two new stratigraphical subdivisions are proposed, the 'Boola Beds' for the stratigraphical equivalents of the Tanjil Beds in this area, and the 'Coopers Creek Formation' to replace the 'Basal Conglomerates and Limestones of the Walhalla Beds'. 28 tabulate coral species, 33 rugose coral species, subspecies and varieties, 26 brachiopod species, 6 lamellibranch species and 4 trilobite species, are described. These (together with 19 stromatoporoid species not described here) represent the more common invertebrate species of the fauna. Their distribution through 57 fossil localities is noted. New taxonomic categories proposed are the tabulate corals *Favosites hillae* sp. nov., *F. coactilis* sp. nov., *F. macilentus* sp. nov., *Natalophyllum callidum* sp. nov., *Fossopora quintaria* sp. nov.; the rugose corals *Syringaxon* (*Saucrophyllum*) *pocillum* subgen. et sp. nov., *Pseudamplexus princeps* (Etheridge) var. *confertus* var. nov., *Disphyllum cognatum* sp. nov., *D. incongruum* sp. nov., *Tipheophyllum ops* sp. nov., *Tabulophyllum meridionale* sp. nov., *Dohmophyllum pridianum* sp. nov., *Lyriolasma subcaespitosum praecursor* subsp. nov., *Tryplasma etheridgei* sp. nov.; the brachiopods *Dolerorthis persculpta* sp. nov., *Onniella tyerseusis* sp. nov., *Tyersella typica* gen. et sp. nov., *Resserella impensa* sp. nov., *Isorthis festiva* sp. nov., *Strophonella gippslandica* sp. nov., *Plectatrypa australis* sp. nov., *Lissatrypa lenticulata* sp. nov., *Delthyris* (*Howellella*) *scabra* sp. nov.; the lamellibranch *Ctenodonta* (*Practenodonta*) *raricostae* (Chapman) subgen. nov.; the trilobite *Leonaspis bispinosa* sp. nov.

Introduction

In common with most of the Silurian and Devonian sediments of the Walhalla Synclinorium, the area around the lower Tyers R. has received very little attention, so that the faunas are virtually unknown. As early as 1907, Chapman (p. 70) stated of some specimens of limestone collected from the limestones outcropping along the Tyers R.—'They are rich in crinoid and coral remains, and the particular bed from which they were taken promises eventually to be a veritable storehouse of Silurian fossils'. Chapman's prediction was well founded. The present paper deals with the description of 97 of the more common invertebrate species (apart from the stromatoporoids) from this and the underlying horizons. In all it is estimated that over 200 invertebrate species are represented in the fauna.

When this work was started in 1955, it was intended to map and study the faunas of all the limestone horizons of the Walhalla Synclinorium. However the Tyers area, to the extreme S. of the main outcrop belt of these Palaeozoic rocks, proved so richly fossiliferous that the original plan was abandoned and this area was studied in detail. The present paper should provide a basis for the description of the rest of the faunas of the Walhalla Synclinorium at this stratigraphic level.

The area investigated is approximately 2 m. by 1½ m. and is situated about 5 m. NW. of the township of Tyers, about 70 m. E. of Melbourne. To the N. and E. of this area the Palaeozoic rocks are obscured by Tertiary basalts and sediments

capping the Boola spur, which carries the main Tyers-Erica road, while to the S. they disappear beneath the Jurassic rocks of the Tyers Group. The W. boundary of the area is marked by the virtually unfossiliferous Walhalla Beds. Most of the area lies within the Parish of Boola Boola, but that portion W. of the Tyers R. is in the Parish of Tanjil East. National Grid Co-ordinates are shown on the map (Fig. 1). As with most of the outcrop area of the Palaeozoic rocks of this region, the country is rough and heavily timbered. Exposures in the area are poor apart from quarries, road cuttings and river sections. Thus, as the area did not lend itself to accurate geological mapping, many of the boundaries shown in the geological map are inferred.

In all, several thousand specimens were collected from 57 fossil localities in the area. In the study of the fauna of the limestones of the order of 2000 thin sections were prepared. The collection is housed in the Melbourne University Geology Department where most of the work was undertaken. The final draft of portions of the manuscript was prepared during the tenure of a Commonwealth Scientific and Industrial Research Organization Overseas Studentship, at the Sedgwick Museum, Cambridge.

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Previous Investigation

Murray (1876) was the first to mention the occurrence of limestones outcropping in the area investigated. He states (p. 40)—‘In the Tyers River are very hard schists and silicious sandstones, and in a small tributary east of the river is a band of dark-grey limestone, with indistinct fossil markings and corals . . .’. In 1887 (p. 44) he again remarked on the occurrence of limestone along the Tyers R. and (p. 15) listed its age as Upper Silurian, this apparently being based on comparison between it and the limestones at Coopers Creek, which McCoy had suggested were Upper Silurian on ‘very imperfect palaeontological grounds’. Murray (1889) again gave a more detailed account of the limestone occurrences.

Chapman (1907) has been the only author to identify any fossils from the

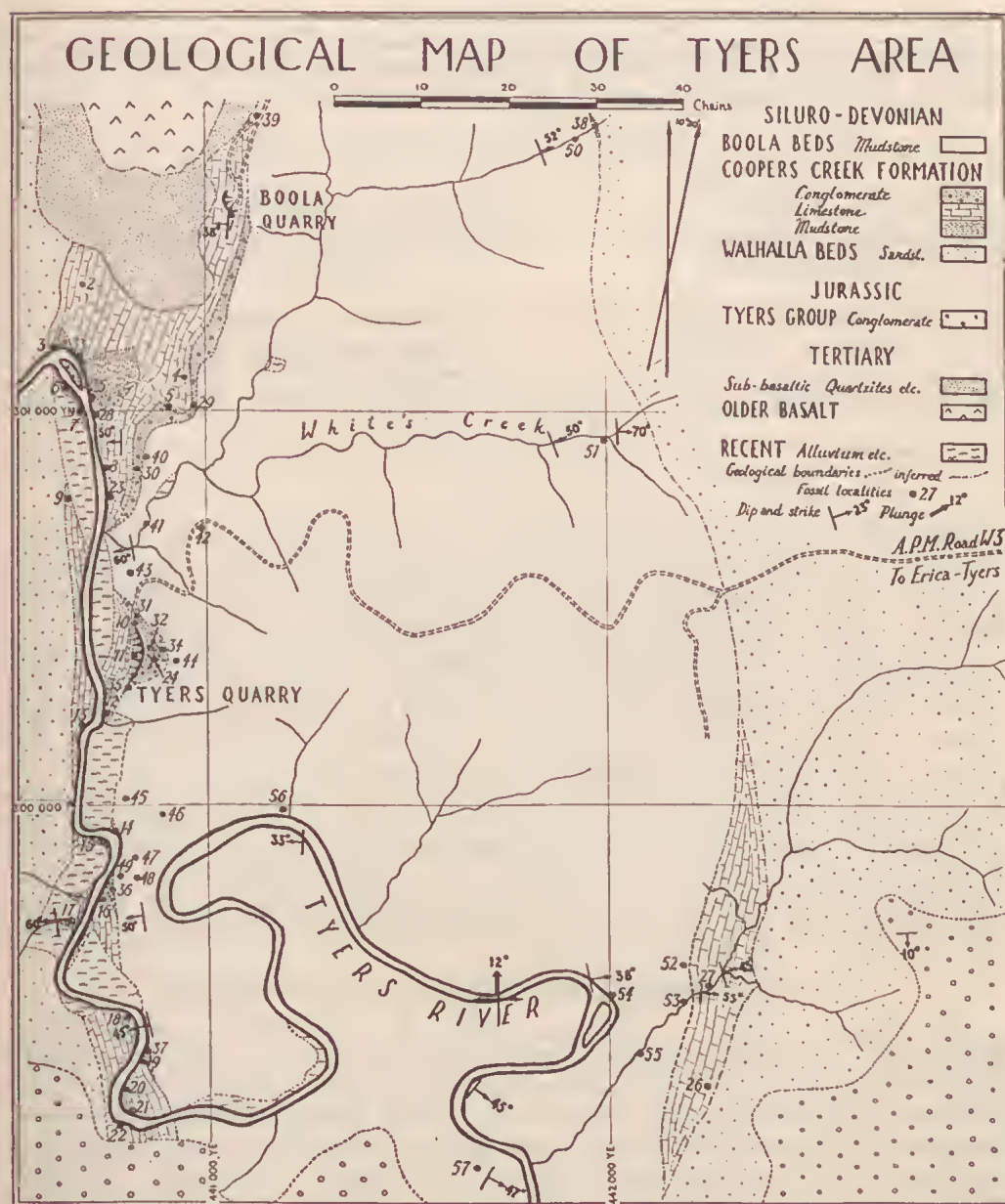


FIG. 1.

area. Shown below are Chapman's determinations, as interpreted in this paper. It is unfortunate that Chapman's specimens could not be found, either in the Geological Survey Museum or in the National Museum, Melbourne, and so the forms have been interpreted from Chapman's figures and descriptions.

Chapman 1907	Here identified
<i>Girvanella conferta</i> sp.nov.	<i>G. conferta</i> Chapman
<i>G. cf. incrustans</i> (Wethered)	<i>G. cf. incrustans</i> (Wethered)
<i>G. (?) pisalítica</i> (Wethered)	<i>G. (?) pisalítica</i> (Wethered)
<i>Manatrypa</i> sp.	?
<i>Favosites gothlandica</i> Lamarck	<i>F. gothlandicus</i> Lamarck
<i>Cannapara australis</i> sp.nov.	<i>Favosites squamuliferus</i> forma <i>australis</i> (fide Philip 1960a)
<i>Rhombapara gippslandica</i> sp.nov.	<i>Caenites</i> (<i>Cladopara</i>) <i>gippslandica</i> (Chapman)
? <i>Palaeechinus</i>	?

Chapman suggested that certain of the rocks he examined from Tyers were 'from a volcanic tuff, more or less basic in character, with minute chips of quartz and some chlorite'. Although this describes the thin section appearance of typical mudstones of the Boola Beds, they certainly are not tuffaceous in character.

Kenny (1937) mapped the limestone leases along the Tyers R. and described the general geology of the area in some detail. Portions of the area occurring in the Parish of Tanjil East had previously been mapped by Whitelaw (1926). Although Thomas (1942) had broadly elucidated the structure and stratigraphy of the Palaeozoic rocks of the Gould-Platina district, his work did not extend as far S. as the Tyers area. More recently the writer (1958) has given an account of the Jurassic rocks outcropping in the S. part of the area, (1960a) described in detail the squamulate favositids of the limestone horizons, and (1960b,c) given a preliminary account of the Tyers fauna and its bearing on Victorian Silurian and Devonian correlations. Talent and Philip (1960) also make brief mention of the limestone along the Tyers R. with regard to its probable sedimentary environment.

Geological Structure and Stratigraphical Subdivisions

The Palaeozoic rocks in this area are folded in a broad anticline with steeply dipping limbs. This structure has been traced further to the N. by Thomas (1942). Exposures of the Boola Beds, which occupy the core of the fold, are poor, and in the central part of the area the rocks are very strongly jointed and rubbly. Moreover, nowhere in the series is the bedding at all apparent. For these reasons reliable dip readings were almost impossible to obtain. Thus the anticlinal axis was recognized only in one place on the N. bank of the Tyers R. in the S. part of the area. The fold here has an extremely broad rounded crest with gently dipping limbs. It is almost symmetrical and plunges northward at about 12°. This plunge is apparently local, as 10 m. further N. at Coopers Creek the Boola Beds have virtually the same width of outcrop in the core of the fold.

No major faulting was recognized in the area, although minor faults were observed in many of the road cuttings and quarries. The stratigraphic subdivisions recognized within the area are:

(A) BOOLA BEDS

This name is proposed for the thick, uniform mudstone series outcropping in the core of the Tyers anticline. Their base is not recognized, but they pass up conformably into the Coopers Creek Formation ('Basal Beds of the Walhalla Series'). The unit is thus the stratigraphical equivalent of the Tanjil Beds to the W., but as continuity with this unit cannot be proved, and because, due to its richly fossiliferous nature, the unit requires some reference name, this name is suggested, derived from the Parish name 'Boola Boola'. Should the '*Monograptus uncinatus*' horizon be recognized within the Tyers anticline, then this could provide a suitable base to the unit.

Lithologically the Boola Beds consist of massive mudstones usually without even a trace of bedding. Toward the core of the anticline and on its E. side they are strongly jointed. In thin section they consist of fine, poorly sorted, subangular quartz grains set in a matrix of chlorite, clay minerals and finer detrital material. They are grey-green in colour when fresh, but weather to a red-brown. Their absence of bedding and their strong jointing preclude any accurate measurement of their thickness, but it is estimated that they are at least 600 ft thick in this area.

In the top 100 ft of the unit the mudstones may become calcareous and strongly cemented with carbonate and so approach an impure limestone. Also toward the top of the unit are intercalated lenses of fine conglomerate consisting of sub-rounded chert fragments in a mudstone matrix. In the top 30 ft of the formation these may become dominant so that the junction between the Boola Beds and the overlying conglomerates of the Coopers Creek Formation is gradational. Although the lower part of the unit is virtually unfossiliferous, the upper part (the top 100 ft of the unit) contains an abundant invertebrate fauna. The distribution of fossil forms from the various localities within the Boola Beds is shown in Table 1.

(B) COOPERS CREEK FORMATION

This name is proposed for the limestone-conglomerate association which occurs on the flanks of the Tyers anticline. The name is taken from Coopers Creek further to the N., where the formation is more readily accessible, and from where it was first described adequately. The name replaces the term 'Basal Conglomerates and Limestones of the Walhalla Beds' present in the literature. The formation is a well-defined marker horizon in the Walhalla Synclinorium, where, on the W. side, it has been traced for over 50 m., and so it warrants a shorter and more correctly formed stratigraphic name.

The most notable feature of the formation is the very diverse and rapidly changing lithologies it exhibits. This has led to great difficulties not only in the quarrying for limestone but also in geological interpretation. It originally led Stirling (1899, p. 23) to postulate of the conglomerate that 'the breccia itself crosses the limestone belt and is of volcanic origin, occupying an immense strike fault in the Silurian rocks'. Later, Herman (1901) noted 'a gradual transition in texture can be traced from the coarse fossiliferous conglomerate to a schistose granular rock similar to that constituting the cementing matrix of the conglomerate; thence through fossiliferous shales with crinoid stems to highly calcareous encrinital shales, and finally to encrinital limestone or marble'.

Within the formation it is proposed to recognize the different lithologies as distinct sedimentary phases. It is not practicable to recognize members within the formation as the different rock types bear no relationship to their stratigraphic occurrence. Thus Thomas (1942) recognized 6 separate limestone lenses at Coopers

Creek at different stratigraphic levels within the conglomerate. He states (p. 359) that 'two small worked-out quarries between Coopers Creek and Platina Railway Station are at the base, three others are on the upper surface of the conglomerate, while White Rock Quarry is in the conglomerate but near the base'. The situation is not as complex as this in the Tyers area. On the W. side of the anticline the conglomerate is always at the base of the formation and passes up into a thick continuous limestone horizon. The only sizable limestone lens within the conglomerate is at the back of the old Tyers Quarry (Loc. 24). On the E. side of the anticline toward the S. the conglomerate is completely absent and a thick limestone horizon directly overlies the Boola Beds (Loc. 26, 27). To the N. of this the formation is virtually absent, represented merely by a thin calcareous conglomerate horizon.

Thus, not only do the lithologies of the formation vary rapidly but also does the thickness of the formation. On the W. side of the anticline at Tyers the thickness is of the order of 300 ft, the lower 50 ft or so usually conglomeratic, reaching a maximum thickness to the N. of over 400 ft. On the E. side the maximum thickness reached is slightly more than 300 ft, but, as has been mentioned, the formation is usually almost absent. 10 m. further N. at Coopers Creek the situation is very different as the main development of the formation (more than 500 ft thick) is on the E. side of the fold, with the minor outcrop to the W.

The sedimentary phases recognized were:

(1) CONGLOMERATE PHASE. Mapped as such are the rocks containing more than 50% pebbles. Although pebbles of igneous rocks are present within the conglomerate elsewhere (Junner 1914) here they were exclusively found to be of well rounded cherts, usually less than one inch across. The matrix of the conglomerate is of finer detrital material, or, more commonly, the conglomerate was apparently cemented by carbonate which has been lost on weathering. The conglomerate phase is usually confined to the base of the formation, but may occur toward the top (Loc. 33) and pebbles may be found throughout the limestone. In this area the conglomerate reaches a maximum thickness of 100 ft.

(2) LIMESTONE PHASE. The rock type representing this phase ranges from a typical grey limestone through into conglomeratic rocks or even silty, impure limestones. Typically toward its base the limestone is well bedded with the higher horizons more massive. In general it is a coarse calcarenite made up essentially of comminuted bioclastic debris, mainly corals, stromatoporoids and, to a lesser degree, algae. To the N. as in Boola Quarry, the rock approaches more a calcilutite, but exposures are poor in this part of the area away from the Tyers R.

(3) MUDSTONE PHASE. This term is used to describe mappable mudstone and sandy mudstone lenses within the formation. The phase is not well developed in this area, but at Coopers Creek thick mudstones have been described within the formation (Thomas 1942).

A typical section through the formation is exposed along the Tyers R. in the vicinity of Loc. 18. Here the top members of the Boola Beds are seen to contain chert pebbles which become progressively more abundant higher in the section until the rock becomes a conglomerate with a mudstone matrix. In turn, this is replaced by a limestone cement, and, with a gradual decrease in the abundance of chert pebbles, the rock grades up into a limestone. All these rocks are well bedded in units usually slightly less than one foot thick. It is noteworthy that these beds within the base of the formation are graded. A typical bed from the base of the limestone

10 in. thick shows the lower part to be made up of large chert pebbles, rounded colonial corals, and large crinoid ossicles set in a coarse calcarenite. This coarse material slowly decreases in size up through the bed so that the upper 3 in. consists of a fine calcilitite, which in weathered specimens may be capped by a very thin, fine shale parting. This well bedded limestone passes up into more thickly bedded, massive limestone with no grading apparent within the units.

The exposures of the Coopers Creek Formation are particularly fine along the valley of the Tyers R., where the river follows the outcrop of the formation for over a mile. This allowed fairly detailed collecting, particularly of the limestone, from the river cliffs and natural exposures. The faunas of the various localities in the different sedimentary phases are tabulated in Table 1.

(C) WALHALLA BEDS

The Coopers Creek Formation is conformably overlain by the sandstones and mudstones of the Walhalla Beds. In this area the only fossils they were found to contain were plant remains.

Composition of the Tyers Fauna and Flora

In this section it is proposed to review the main groups of organisms identified in the collections from the Tyers area, particularly those not described in this paper.

SPONGES

One fragmentary sponge, possibly a receptaculitid, was collected from Loc. 21 in the Limestone Phase of the Coopers Creek Formation.

STROMATOPOROIDS

Stromatoporoids form a very important element in the fauna of the Coopers Creek Formation, both in species and relative abundance. The stromatoporoids of this area, together with those from the Lower and Middle Devonian limestones elsewhere in Victoria, are to be described separately, however the distribution of the species recognized is given in Table 1. 4 new species are present in the fauna, 3 of which are known only from this area, while the fourth is present also at Loyola (*Anostylostroma* sp. nov. A = *Clathrodictyon regulare* v. Rosen of Ripper 1937a). Those species previously recognized elsewhere in Victoria are *Stromatoporella granulata* from Lilydale, and recorded from Buchan by Talent (1956a), *Actinostroma verrucosum* (Goldfuss) from Lilydale, *Stromatopora bucheliensis* (Bargatzky) from Loyola and Lilydale, *S. foveolata* (Girty) from Lilydale, *S. typica* v. Rosen from Loyola, *Parallelopora lilydalensis* (Ripper) from Lilydale, *Hermatostroma loomberensis* (Dun) from Buchan (= *Hermatostroma episcopale* Nicholson of Ripper 1937b). *Amphipora ramosa* (Phillips) has been recorded from the Middle Devonian of Buchan by Teichert (in Teichert and Talent 1959), but the record is apparently based on the occurrence of a species of digitate calcareous alga, as this is all the writer has been able to discover at the stratigraphic level of his 'Amphipora' biostrome in the Murrindal Limestone. The remaining 7 stromatoporoid species, previously described from Europe and Russia, are recorded from Australia for the first time.

Certain interest may be attached to this Lower Devonian stromatoporoid fauna, as faunas of this age are extremely rare throughout the world. As such it can be seen to be a peculiar admixture of Upper Silurian and Middle Devonian species known from elsewhere in the world. This may be illustrated best by the species of *Actinostroma*: *A. intertextum* Nicholson and *A. jurmanense* Yavorsky are elsewhere

TABLE 1 (continued)

[illegible]

r = rare; o = occasional; c = common; a = abundant; ? = questionable occurrence.
 † Mudstone Phase interbedded with limestone. • Limestone Phase of Coopers Creek Formation on E. limb of anticline.

TABLE 1 (continued)

confined to the Silurian, *A. salairicum* Yavorsky is a Middle Devonian species, *A. bifarium* Nicholson is a Middle and Upper Devonian species and *A. verrucosum* (Goldfuss) is also typically Devonian.

A similar interest may be attached to the coral fauna, which is described in some detail in this paper.

In Table 1 stromatoporoids appear to be much more abundant in certain localities than in others. This could be due largely to a bias in collecting as in those localities, because of the manner in which the rock was superficially weathered, they were much more apparent in the hand specimen than normally.

Stromatoporoids are virtually confined to the Coopers Creek Formation, particularly the limestone phase, only one solitary specimen of *Stromatopora typica* having been collected from a calcareous horizon in the upper part of the Boola Beds (Loc. 50).

TABULATE CORALS

Tabulate corals are by far the most important element in the Limestone Phase of the Coopers Creek Formation from the point of view of abundance, and they are commonly met with in the upper part of the Boola Beds. 28 species were recognized distributed through 13 genera and subgenera. 6 of the species are new.

Represented in the Boola Beds are 11 species, 2 of which, *Favosites moonbiensis* and *Cocnites* (*Cocnites*) *planifolium* sp. nov., are confined to that unit. Of the remainder *Pleurodictyum megastoma* ranges up into the Conglomerate Phase of the Coopers Creek Formation, but was not collected in the Limestone Phase. The rest continue through into the Limestone Phase of the Coopers Creek Formation where they are joined by 17 other species confined to that Formation. The species which survived the major facies change at the top of the Boola Beds then are *Favosites forbesi*, *F. coactilis*, *Thamnopora boloniensis*, *Cocnites* (*Cladopora*) *gippslandica*, *Pleurodictyum megastoma*, *Heliolites daintreei*, *Plasmopora gippslandica*, and *Aulopora* sp. affin. *A. emergens*. The various formae of *F. squamuliferus* (fide Philip 1960a), which make up the majority of the specimens of tabulate coral collected from the limestone, are not represented in the Boola Beds except for a single specimen of *F. squamuliferus* forma *nitidus* collected from Loc. 47. Those species confined to the Coopers Creek Formation are *Favosites gothlandicus*, *F.* sp. affin. *F. forbesi*, *F. goldfussi*, *F. hillae*, *F. allani*, *F.* sp. cf. *F. inosculans*, *F. macilentus*, *Favosites* sp., *F. squamuliferus* (?), 'Emmonsia' sp. cf. *E. fusta*, *Alveolites* sp. cf. *A. taenioformis*, *Alveolites* sp., *Thamnopora alterivalis*, *Natalophyllum callidum*, *Cocnites* (*Cladopora*) *foliata*, *Fossopora quintaria*, and *Roemeria thomii*. Of these *F. forbesi*, *F. goldfussi*, *F.* sp. cf. *F. inosculans* occur in the conglomerate phase as well as the limestone phase.

The most common of the widely distributed species are *Favosites forbesi*, *Cladopora gippslandica*, and to a lesser degree *Heliolites daintreei*, while in the Limestone Phase of the Coopers Creek Formation, *Favosites squamuliferus* occurs in profusion.

RUGOSE CORALS

Rugose corals are widely distributed throughout the area. 32 species and varieties are described belonging to 21 genera. Of these, 6 species, one subspecies and one variety are described as new, and one new subgenus of *Syringaxon* is recognized. From the great number of indeterminate fragmentary remains in the collection it is estimated that at least a further 20 species are present in the fauna, mainly confined to the Coopers Creek Formation.

The rugose corals of the Boola Beds consist of fairly common solitary non-

dissepimented or poorly dissepimented forms such as *Syringaxon*. In this category also are a number of small solitary species, usually preserved as moulds, similar to the species from the Melbourne district described by Chapman (1925) in the genus *Lindstroemia*. In the absence of sufficient specimens in which the hard parts were preserved no serious attempt was made to identify these forms. They are referred to as '*Streptelasma*' spp. in Table 1. These solitary forms range up into the basal conglomerate phase of the Coopers Creek Formation. Also present in the Boola Beds are the cystiphyllinids *Microplasma*, *Tryplasma*, *Rhizophyllum* (?) and indeterminate cystiphyllids. This fauna, composed mainly of solitary non-dissepimented forms, parallels the '*Cyathaxonia*' fauna of the Carboniferous (*vide* Hill 1948) in which the presence of such fauna is taken as an indication that their environment was water, 'cold, deep or murky'.

As opposed to this, the Limestone Phase of the Coopers Creek Formation contains many different species of large solitary dissepimented forms together with compound forms. 26 of the species described are confined to the Coopers Creek Formation, 5 are present only in the Boola Beds, and one was found in both units. This suggests that the rugose corals here were much more sensitive to their environment than were the tabulate corals as nearly one-third of the tabulate species survive the facies change between the Boola Beds and the Coopers Creek Formation.

Although many species are present in the limestone the only forms which are at all common are *Hexagonaria approximans*, *Thamnophyllum reclinatum*, *Acanthophyllum mansfieldense* and, to a lesser extent, *Pseudamplexus princeps*.

Rugose corals were found to be rare in the conglomerate phase of the Coopers Creek Formation. *Pseudamplexus princeps* was the only species collected apart from solitary laccophyllids and '*Streptelasma*'.

SCYPHOZOANS

A single fragmentary specimen of a species of *Conularia* was collected from Loc. 46 in the Boola Beds.

BRACHIOPODS

Brachiopods represent the most common element of the fauna of the Boola Beds and are also well represented in the Conglomerate Phase of the Coopers Creek Formation. However, they are extremely rare in the Limestone Phase. The common association of genera in the Boola Beds is *Lissatrypa* and *Plectodonta* sometimes joined by *Notoleptaena*, *Chonetes*, *Notanoplia* and more rarely *Ouniella*. In the more calcareous horizons this fauna is to some extent replaced by other genera such as *Atrypa*, *Plectatrypa*, *Strophonella*, *Leptostrophia*, *Dolerorthis*, *Isorthis*, *Resserella*, *Tyersella*, *Howellella*, etc. Many of these forms, in particular *Tyersella*, *Resserella* and *Atrypa*, range up into the Coopers Creek Formation where they are commonly encountered in the Conglomerate Phase. *Ucinulus* (?) alone is widely distributed through the Coopers Creek Formation to which it appears to be confined. Other brachiopods, such as *Leptaena*, *Atrypa*, *Chonetes* and *Tyersella* are known only from a few fragmentary specimens from the limestone.

In all, it is estimated that over 35 brachiopod species are represented in the collection. Those forms not described here are known in general only from one or two incomplete valves which do not admit even of generic determination.

LAMELLIBRANCHS

Occasional lamellibranchs were found in various localities toward the top of the Boola Beds. Only the more complete of these are described in this paper. Lamelli-

branches are rare in the Coopers Creek Formation where *Actinopteria* sp. and (?) *Conocardium costatum* (Cresswell) are known from single specimens in the conglomerate and limestone phases respectively.

GASTEROPODS

Fragmentary remains of gasteropods were collected from a number of localities toward the top of the Boola Beds, but most of the forms found were indeterminate apart from *Straparolus* sp. (Pl. XXIX, fig. 19) and a species of *Orthonychia*. Gasteropods in general were rare in the Coopers Creek Formation. At Loc. 21 and 22 in massive limestone on the bank of the Tyers R., sections through extremely large examples of a *Loxonema* type of gasteropod up to 8 in. high were seen. Also at Loc. 21 were present specimens of a large trochiform species probably related to the genus *Scalaetrochus*. These specimens could not be collected from the massive limestone. Small bellerophonitid forms were also encountered in thin sections of the limestone from Loc. 4, 11 and 21. The gasteropods of the fauna are not described here.

PTEROPODS

Pteropods, mainly species of *Hyolithes*, were found widely distributed throughout the upper part of the Boola Beds. At least 3 species were present in the collection. It is noteworthy that the pteropod *Styliolina*, so characteristic of rocks of Tanjilian age elsewhere in Victoria, was not discovered in the Boola Beds. Pteropods were not discovered in the limestone or conglomerate.

NAUTILOIDS

Flattened remains of large orthoconic and more rarely breviconic nautiloids were encountered toward the top of the Boola Beds at Loc. 40, 41, 43, 45, 47, 48, 49. Other nautiloids were collected from the limestone at Loc. 11 and 27. One of the specimens from Loc. 11 was extremely large, slightly under one foot in length.

TRILOBITES

Trilobites, although virtually absent from the Coopers Creek Formation, were found to be widely distributed and fairly common in upper localities of the Boola Beds. 5 species are present in the collection, one of which, represented solely by a single fragmentary phacopid cephalon, is not described here.

OSTRACODES

Well preserved beyrichian ostracodes were abundant in localities toward the top of the Boola Beds. Ostracodes were also noted in some of the thin sections of the limestone. No attempt was made to identify the forms present.

ECHINODERMS

Crinoid stem ossicles were common in the upper part of the Boola Beds, and also throughout the Coopers Creek Formation, particularly in the limestone, which in places may be made of them to the exclusion of all other forms. No identifiable crinoid remains were discovered here, but further to the E., N. of Toongabbie, a crinoid fauna has been found on the same horizon as the Coopers Creek Formation. This is to be described elsewhere. A solitary, beautifully preserved brittle-star, probably conspecific with *Crepidodoma kinglakensis* Withers and Kehle, was collected from Loc. 45. Chapman (1907) also records that spines of *Palaeoechinus* are common in the limestone, but nothing in the present collection could be so identified.

PLANTS

Land plants of the same general type as *Yarravia* and *Hostimella* are abundant through the upper part of the Boola Beds and the Walhalla Beds, but were not found in the Coopers Creek Formation. One single specimen of *Baragwanathia* was collected from Loc. 45 in the Boola Beds.

Algae were often seen in thin sections of the limestone of the Coopers Creek Formation. Chapman (1907) described 3 species of *Girvanella* from the Tyers limestones. All these forms were seen in thin sections although no serious attempt was made to identify them. Also present at a number of localities is a species of digitate codiacid alga which will be described at a later date, along with those of other Devonian limestones of Victoria.

During the field work a particular search was made for fish remains, but none was found. Foraminifera, worms and conodonts were not recognized in the collection.

Faunal Succession and Palaeo-Ecology

The lack of fossil localities in the central part of the Tyers anticline (Fig. 1) is due entirely to the unfossiliferous character of the lower part of the Boola Beds. In the stratigraphically lowermost of the fossil localities (Loc. 56, 57) fossils are extremely rare. At Loc. 56 a single specimen of *Notoleptaena otophera* was collected, while at Loc. 57 two specimens of '*Streptelasma*', one of *Lissatrypa lenticulata* and fragmentary plant remains were obtained after a considerable time had been spent on the outcrop. Between about 300 ft and 150 ft from the top of the Boola Beds fossils are more common than this, but are by no means abundant. The common association is the brachiopods *Lissatrypa lenticulata* and *Plectodonta bipartita*, more rarely with *Notoleptaena otophera*, solitary corals and hyolithids. Still higher, about 150 ft from the base of the Coopers Creek Formation, these may be joined by other brachiopods such as *Chonetes*, *Notanoplia*, *Onniella*, *Eospirifer* and lamellibranchs. The more calcareous phases may also contain tabulate corals such as *Favosites* spp. and *Plasmopora*, and also trilobites and ostracodes. *Lissatrypa* and particularly *Plectodonta* occur in great numbers at this horizon. In the upper part of the Boola Beds, immediately beneath the Coopers Creek Formation, the unit may be highly calcareous and richly fossiliferous, containing abundant tabulate corals, brachiopods, and trilobites, but the *Plectodonta-Lissatrypa* association is absent, although these forms may be found in the more barren horizons surrounding the calcareous patches.

With the incoming of the basal conglomerate beds of the Coopers Creek Formation, the character of the fauna is changed, although many of the tabulate corals return in the more calcareous phases. Brachiopods such as *Tyersella*, *Resserella*, *Atrypa*, *Eospirifer* survive the facies change, but corals are rare. The conglomerates then gradually grade up into the limestone phase, with its rich and diverse coral-stromatoporoid fauna. It is of interest that both *Lissatrypa* and *Plectodonta* occur again in the Mudstone Phase of the Coopers Creek Formation. Presumably this represents a local return to a similar sedimentary environment to that of the Boola Beds.

It appears then that, during the deposition of the Boola Beds, conditions slowly became more favourable for the development of a large invertebrate community (or, at least, the preservation after death of such). Talent and Philip (1960) have suggested that this probably was due to a shallowing of the basin of deposition. The Coopers Creek Formation, with its basal conglomerate phase, represents a major change in the conditions of deposition, namely the entry of coarse detrital material

into the sedimentary basin. It is noteworthy that the lower part of the formation is graded. This, together with the rolled and broken appearance of many of the fossils, suggests that at least the lower part of the formation was derived from a neritic zone elsewhere containing pebble banks, and, from the character of the fauna, coral-stromatoporoid reefs. This bioclastic debris and coarse detrital material was apparently deposited in the Tyers area by a type of density current deposition.

The incoming of the Walhalla Beds marked an abrupt end to this phase of deposition and a return to the normal geosynclinal sedimentation under which conditions most of the sediments of the Walhalla Synclinorium were deposited.

Age of the Sediments

This question has been dealt with in some detail elsewhere (Philip 1960b) together with the relation of the Tyers section to rocks of similar age elsewhere in Victoria (see also Addendum to this paper).

Briefly, the fauna of the Boola Beds suggests an Upper Silurian age (the genera *Lissatrypa*, *Plectatrypa*, *Dolerorthis* and perhaps *Resserella* appear to be confined to Silurian rocks elsewhere in the world). The only Devonian elements in the fauna are perhaps the trilobite *Cheirurus* (*Crotalocephalus*) *silverdalensis* (which, however, was originally described from the Silurian of Yass, N.S.W.) and the coral *Pleurodictyum* which apparently ranges down into the Silurian in E. Australia. On the other hand, the coral fauna of the Coopers Creek Formation, in comparison with those of the European sections, suggests an upper Lower Devonian age. This fact, together with other coral occurrences in E. Australia, has led the writer to suggest that a homotaxial relation exists between the shelly fossils and corals in comparison with the faunas of Europe. It has further been suggested that the facies change between the top of the Boola Beds and the Coopers Creek Formation should be taken as the Siluro-Devonian boundary in Victoria, as this represents a mappable horizon within the Walhalla Synclinorium which approximates to this time boundary.

Although it is doubtful whether this horizon can be detected biostratigraphically in the sequences of Lilydale and Heathcote, another reason for its choice is that the entry of coarse clastics in the Tyers sequence at the base of the Coopers Creek Formation marks a definite phase in the tectonic history of the Tasman Geosyncline. It was probably due to the uplifting of Cambrian rocks along the Mt Wellington axis to the E. which can be correlated with the Bowning phase of the Palaeozoic orogeny in E. Australia. Thus the Bowning phase may be taken to be at the end of the Silurian in Victoria at least, and the effects of this phase may perhaps be likewise detected in the other sequences.

The Upper Silurian age of the Boola Beds on the basis of shelly fossils has an indirect bearing on the age of the *Baragwanathia* flora which occurs at the base of the Tanjil Beds (stratigraphical equivalent of the Boola Beds). Jaeger (1959) has recently suggested from illustrations that the species of graptolite which occurs associated with the flora is *Monograptus hercynicus* rather than *Monograptus uncinatus* as it has previously been identified. If this is so then the 'Tanjilian' is equivalent only to the Upper Ludlow.

However, Solle (1959) has suggested that the graptolites associated with the plants are derived from older rocks and the *Baragwanathia* flora is Devonian in age. Although this view is completely untenable on general grounds alone, it is of interest that the upper part of the equivalents of the Tanjil Formation are now dated as Upper Silurian on the basis of shelly fossils.

Systematic Descriptions
PHYLUM COELENTERATA
Class ANTHOZOA

In the coral descriptions below, the terminology is that of Hill (1956a) for rugose corals and that of Hill and Stumm (1956) for tabulate corals. Regarding the tabulate corals, some of the descriptive terms are to be found in Swann (1947) or have been discussed elsewhere (Philip 1960a).

Order TABULATA

With reference to the tabulate corals the monograph of Sokolov (1955) should be mentioned. A copy of this became available to the writer only after the section on corals was completed, so Sokolov's views are only mentioned when they have a direct bearing on the identification or interpretation of the Tyers specimens. The main feature of Sokolov's work is the extremely elaborate and artificial classification he proposes for the tabulate corals. In doing this, Sokolov has found no new taxonomic criteria on which to base his enormous number of suprageneric categories; the features used are the basis of the existing tabulate coral classifications, but whereas other authors have recognized and respected the extreme plasticity of the group, Sokolov has thrown all caution to the winds. Thus the suborders of his 'Tabulata Communicata' are based on features which I would regard as being of doubtful generic merit. However it is outside the scope of this present paper to review Sokolov's work, a task which in itself would be monumental.

Family FAVOSITIDAE Dana
Genus *Favosites* Lamarck 1816

Favosites gothlandicus Lamarck
(Pl. XI, fig. 1-2)

Favosites gothlandica Lamarck 1816, p. 206.

? *Favosites gothlandica* Lamarck, Chapman 1907, p. 72 (*partim*), Pl. 2, fig. 5.

Favosites gothlandicus Lamarck forma *gothlandica* Lamarck, Jones 1937, p. 86, Pl. 11, fig. 1-2 (see for corrections of earlier Australian occurrences); Hill and Jones 1940, p. 193; Hill 1954a, p. 42, Pl. 4, fig. 13a-b.

DESCRIPTION: Corallum globose, sub-hemispherical, diameter greater than 5 cm.

Corallites polygonal, gently radiating, diameter uniform, up to 3.5 mm, usually averaging about 2.5 mm; walls moderately thin, between 0.08 and 0.12 mm, but reaching up to 0.5 mm in places showing strong growth wrinkling.

Tabulae horizontal, flat, sometimes highly inclined for up to 3 cm in the one corallite; regularly spaced, 6 to 10 per cm, moderately thin.

Mural pores circular, typically biserial, alternate, occasionally slightly rimmed, spaced on the average 1 mm apart, ranging from 0.15 to 0.35 mm in diameter. Pore plates occasionally present.

No septal apparatus.

FIGURED SPECIMENS: T. 712-3 cut from M. 2888, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (rare), 11 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The 3 ubiquitous Silurian species of *Favosites*, *F. gothlandicus*, *F. forbesi* E. & H. and *F. multiporus* Lonsdale were examined by Jones (1936) and

considered to be conspecific. These morphological variants which were considered to be due to environmental differences, were regarded as 'formae' within the species *F. gothlandicus* (Jones 1936, 37; Hill and Jones 1940). That these formae were due solely to environment (i.e. ecotypes) can be argued against on general grounds alone. All 3 types may be found occurring side-by-side (Jones records all 3 from the Wenlock Limestone) and thus, as far as can possibly be judged, all existed under the same environmental conditions. It seems rather that the extreme variation exhibited by certain species groups of *Favosites* was due primarily to genotypic variability (Philip 1960a).

Within the collection investigated here, forms corresponding closely with *F. gothlandicus* and *F. forbesi* E. & H. (together with *F. goldfussi* d'Orb. which can well be regarded as belonging to the same species group) occur as stable morphological groups apparently with no intergradation. Accordingly they are regarded as species within their own right.

The only difference between the neotype of *F. gothlandicus* selected and described by Jones (1936) and the form identified as such from Tyers is the much thicker walls of the latter, 0.08 to 0.12 mm as opposed to 0.03 mm in the neotype. The extreme thickness of 0.5 mm given in the above description and present in T. 715 could well be due to a layer of secondary calcite deposited on the walls. In places this secondary layer has buttressed the tabulae which may then simulate septal spines. In Pl. XI, fig. 1 an infilling of drusy calcite is present also in places resembling septal spines.

Although *F. gothlandicus* is a species typical of Silurian rocks throughout the world (Europe, North America, Newfoundland, Asia, Korea, China and Russia) it should be noted that forms closely related to or indistinguishable from *F. gothlandicus* extend through into the Middle Devonian in various parts of the world. Some such species are *F. bohemicus* (Barrande) (Pořta 1902; Schouppé 1954b) from the Lower and Middle Devonian of Bohemia and Austria; *F. helderbergiae* Hall (Loewe 1914) from the Devonian of Ellesmereland; *F. goldfussi* var. *major* Frech (Reed 1908) from the Devonian of Northern Shen States. Further, in view of the similarity and consequent confusion between *F. forbesi* E. & H. and *F. goldfussi* d'Orbigny the time range of the other common Silurian species *F. forbesi* cannot be accurately determined.

The thicker walled forms of *F. gothlandicus* similar to the Tyers form appear to be more characteristic of the Devonian; for example close comparisons can be drawn between it and *F. bohemicus* var. *mosellana* Weissmermel 1941 from the Lower Devonian of the Rheinische Schiefergebirge although the corallites of this form are slightly larger than is typical of the Tyers form.

By far the closest described species to the Tyers form is, however, *F. porfirievi* Chernyshev 1951 from the Lower Devonian of the Kuznetsk Basin. The specimen described by Chernyshev is very closely comparable to our form in all its dimensions. The comparison is complete in that *F. porfirievi* is said to be characterized by horizontal 'ribs' which are apparently the strong growth wrinkles of the corallites as they appear in a longitudinal section lying close to the plane of a wall. The only slight difference which can be seen in the two forms is a tendency for the corallites to be of unequal size in *F. porfirievi*. Whether or not this form is separable from *F. gothlandicus* it is impossible to judge from the material at my disposal. This highlights one of the main problems of favositid taxonomy. The characters by which species are defined are so few that it seems likely that certain 'species', e.g. *F. gothlandicus*, are in fact polyphyletic 'morphogens' with no true genetic relationship. For this reason, and also in view of the great variation which has been ascribed to

the group by Jones, the species group of *F. gothlandicus* has been interpreted as conservatively as possible.

***Favosites forbesi* Edwards & Haime**

(Pl. XI, fig. 4-5; Pl. XXI, fig. 5, 8, 9)

Favosites forbesi Edwards & Haime 1851, p. 238-9.

Favosites gothlandicus Lamarck forma *forbesi* Edwards & Haime, Jones 1936, p. 9-12, Pl. 1, fig. 5-7; Jones and Hill 1940, p. 193, Pl. 5, fig. 4a-b; Hill 1954a, p. 42, Pl. 4, fig. 14.

DESCRIPTION: Corallum variable, usually hemispherical, reaching a diameter of up to 7 cm, occasionally ramose or foliose.

Corallites polygonal, radiating or parallel depending on the shape of the corallum, occasionally showing dimorphism, more often almost uniform in size. Average diameter of corallites varying slightly from specimen to specimen, usually slightly greater than 2 mm, maximum size of corallites up to 3 mm. Where corallites are dimorphic the larger tend to be rounded and 8-sided and between 2 and 3 mm in diameter, the smaller 4-sided and less than 1 mm. Walls thin, between 0.06 and 0.20 mm, normally about 0.08 mm and showing growth crenulations.

Tabulae thin, in most cases horizontal, straight, occasionally imperfect, incomplete, inclined or slightly concave, in places suspended from septal spines, uniformly spaced about 12 per cm, but varying between 10 to 18 per cm.

Mural pores circular, uniserial or more often irregularly biserial, apparently unrimmed, diameter constant between 0.15 and 0.20 mm, spaced uniformly 0.7 mm apart when uniserial, up to 1 mm apart when biserial; pore plates usually present.

Septal apparatus of small, comparatively blunt, horizontally directed septal spines up to 0.13 mm in diameter at their base, circular in cross-section and extending up to 0.25 mm into the lumen. Septal spines arranged in irregular vertical columns about 0.3 mm between the centre of each spine, and up to 0.3 mm between each column, as many as 15 observed in one cycle.

FIGURED SPECIMENS: T.723-4 from M.2892, Loc. 27; M.2926, Loc. 11, Limestone Phase, Coopers Creek Formation. M.2931, Loc. 47; M.2909, Loc. 49, Boola Beds.

OCCURRENCE: Loc. 6 (rare), 7 (occasional), 11 (common), 22 (rare), 27 (common), Limestone Phase; Loc. 28 (rare), 32 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 43 (rare), 47 (occasional), 48 (abundant), 49 (occasional), Boola Beds.

REMARKS: One of the most striking differences between the Boola specimens of *F. forbesi* and material from Dudley, England, sectioned for comparison, was in the septal spines. In the specimens from Dudley the septal spines were up to 0.8 mm long, upwardly directed, and as many as 30 were present in one cycle in an adult corallite. The dimorphism of the corallites was also much more marked in the Dudley specimens. In view of the great variation in both these characters ascribed to this species by Jones (1936) it seems unwise to separate the Tyers form from *F. forbesi*, although it should be noted that Tripp (1933) places considerable taxonomic importance on the development of septal spines and their inclination.

Three other forms in the collection have been referred questionably to this species. The first, represented by T.718-9 from Loc. 27, has slightly larger corallites and also apparently fewer septal spines than is typical of the form identified here as *F. forbesi*, but this could well be due to the preservation of the specimen. In other respects it agrees with *F. forbesi*.

Two specimens from Loc. 5, Limestone Phase, Coopers Creek Formation

(T.756, M.2913 — T.757) appear to differ more significantly from *F. forbesi*. Both sections are through very small coralla, a little over 1 cm in diameter. The corallite diameter is up to 2.6 mm, wall thickness 0.05 mm. The distinction lies in the septal spines, of which there are only a few present. They are blunt, circular in cross section, and upwardly directed, extending up to 0.7 mm into the lumen, 0.2 mm thick at their base and retaining a thickness of 0.1 mm for most of their length. Mural pores were not observed, nor could the spacing of the tabulae be accurately estimated.

F. forbesi is one of the most widespread and common of the Boola favositids, surviving the facies change between the mudstone and the limestone-conglomerate phase.

Favosites sp. affin. **F. forbesi** Edwards & Haime

(Pl. XI, fig. 3)

DESCRIPTION: Corallum sub-hemispherical reaching a diameter greater than 4 cm.

Corallites polygonal, typically 6-sided, averaging 2 mm in diameter. Walls thin, up to 0.1 mm thick, but usually 0.05 mm.

Tabulae thin, horizontal or inclined, straight or occasionally concave, sometimes incomplete, often imperfect, in places suspended from septal spines, spaced about 15 per cm.

Mural pores circular to sub-ovate, with longest dimension horizontal, greatest diameter up to 0.4 mm, usually 0.35 mm but as little as 0.2 mm, uniserial but more typically biserial, spaced fairly uniformly at about 0.5 mm apart. Mural pores rimmed, pore plates usually present.

Septal apparatus of small, broad-based septal spines with slight upward curvature, extending up to 0.2 mm into the lumen, greatly increasing in number distally where they are arranged in poorly defined vertical columns about 0.2 mm apart.

FIGURED SPECIMEN AND OCCURRENCE: T. 784, cut from M. 2925 with T. 783, Loc. 19, Limestone Phase, Coopers Creek Formation (rare).

REMARKS: This form, represented in the collection by a single specimen, may be distinguished from *F. forbesi* primarily in the nature of the mural pores which are almost twice as big and twice as close as those typical of *F. forbesi*. There are also minor differences in the spacing of the tabulae and the nature of the septal spines. What appears to be an almost straight worm tube runs up the middle of one of the central corallites (see Plate) of this single specimen.

Favosites goldfussi d'Orbigny

(Pl. XI, fig. 6-9)

Favosites goldfussi d'Orbigny 1850, p. 107 (*partim*).

Favosites goldfussi d'Orbigny, Jones 1937, p. 94, Pl. 13, fig. 6, Pl. 14, fig. 7 (see for earlier Australian occurrences); Hill and Jones 1940, p. 194, Pl. 6, fig. 2a-b; Jones 1944, p. 34; Hill 1954b, p. 113 (*partim*), Pl. 8, fig. 19 (*non* Pl. 8, fig. 20a-b); Lecompte 1939 and Schouppé 1954b, give full discussion and synonymies for this species.

DESCRIPTION: Corallum sub-hemispherical, largest in collection greater than 6 cm in diameter.

Corallites polygonal, sub-parallel to strongly radiating, typically 5 or 6-sided, usually uniform in diameter and only occasionally showing a tendency toward dimorphism in size. Average diameter of corallites usually slightly under 2 mm, individual corallites up to 2.5 mm, fairly constant in size within the one corallum, but

varying considerably between coralla (T.767—average diameter of corallites = 1.3 mm). Walls moderately thick, diameter between 0.10 to 0.30 mm, usually about 0.13 mm; intermural spaces occasionally present, reaching a maximum diameter of 0.2 mm.

Tabulae moderately thick (0.01 mm), usually horizontal, straight, sometimes highly concave when the tabulae are closely spaced, occasionally imperfect, incomplete or slightly inclined, very often suspended from septal spines. Spacing of tabulae fairly variable, between 8 to 24 per cm, usually about 12.

Mural pores circular to ovate with longest axis parallel to corallite walls, occasionally uniserial but more often irregularly biserial or even triserial, diameter between 1.4 and 3.7 mm, but usually about 2.5 mm. Spacing of mural pores irregular, up to 1.2 mm apart, commonly about 0.6 mm; pore plates mostly present.

Septal apparatus of comparatively pointed, discrete septal spines usually horizontally or upwardly directed. They are about 0.15 mm in diameter at their base, and extend up to 0.4 mm into the lumen, arranged in fairly regular vertical rows with up to 0.4 mm between each spine and with about 0.2 to 0.3 mm between each column.

FIGURED SPECIMENS: T.772 cut from M.2920, Loc. 5; T.764-5 cut from M.2916, Loc. 19; T.770 cut from M.2919, Loc. 23, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 5 (rare), 11 (occasional), 19 (rare), 23 (rare), 27 (occasional), Limestone Phase; Loc. 33 (rare), Conglomerate Phase, Coopers Creek Formation. One poorly preserved specimen (T. 779-80) from Loc. 16 is questionably referred to *F. goldfussi*.

REMARKS: Lecompte (1939) recognized two formae within the species *F. goldfussi*—firstly *F. goldfussi* forma *pyriformis* which is perhaps equivalent to *F. forbesi* var. *eifelensis* Nicholson (regarded by Jones 1936 as based on a 'young form' of *F. goldfussi*)—and secondly *F. goldfussi* forma *regularis*. The difference between these two is gradational, with *pyriformis* characterized by a pyriform corallum and dimorphism of corallites, which when adult are between 2 and 2.5 mm in diameter, whilst *regularis* has a discoidal corallum and slightly larger corallites which are uniform in size. The form here identified with *F. goldfussi* in general shows a fairly uniform corallite diameter although one section, taken from near the base of a corallum, does show a tendency toward dimorphism. The most salient differences between our material and that of Lecompte is that the corallites are smaller, averaging usually less than 2 mm and the tabulae are more distant, usually about 12 per cm as opposed to about 18 per cm in forma *regularis* and even more in forma *pyriformis*. In the size of the corallites and the spacing of the tabulae the species from Tyers is most closely comparable with the Couvinian species *F. saginatus* Lecompte 1939. From *F. saginatus* it differs in the thickness of the walls, and the development of the septal apparatus, both of which are more closely comparable to those of *F. goldfussi*. Thus the Tyers form is intermediate between these two.

F. goldfussi, as well as *F. gothlandicus* Lam. and *F. forbesi* E. & H., has been interpreted somewhat conservatively in view of the very conflicting definitions of different authors, and the great number of species, subspecies and varieties which belong to this species group. At the moment the most satisfactory solution is to equate our local forms with the European species, at the same time recognizing the minor differences between them.

Although Lecompte (1939) is not completely convinced that the Middle Devonian *F. goldfussi* is descended from the Silurian *F. forbesi*, Hill & Jones

(1940) and Regnéll (1941) have recognized the relationship between these species. It is of interest to note then that forms corresponding closely to these species co-existed in the limestones of the Coopers Creek Formation. Hill & Jones (1940) also describe both species from the Garra Beds, N.S.W.

The presence of intermural spaces in one corallum of this species is noteworthy. This appears to be the first record of such in the *F. gothlandicus-goldfussi* group.

F. goldfussi has also been collected from a limestone lens associated with the Coopers Creek Formation, near Telbit Road, Moondarra (T.1204-5; *vide* Thomas 1942, p. 358, for locality).

***Favosites hillae* sp. nov.**

(Pl. XII, fig. 1-2; Pl. XIV, fig. 1-3)

Favosites goldfussi d'Orbigny, Hill 1954b, p. 113 (*partim*), Pl. 8, fig. 20a-b (*non* Pl. 8, fig. 19a-b).

non Favosites goldfussi d'Orbigny 1850, p. 107.

DIAGNOSIS: Moderately thick walled *Favosites* with sub-rounded corallites about 1.3 mm in diameter; evenly spaced horizontal tabulae 30-38 per cm; mural pores circular, strongly pitted, approximately 0.2 mm in diameter, uniserial or occasionally biserial. Septal apparatus variably developed, sometimes almost absent where the walls are thin, usually of moderately long, upward-directed septal spines with as many as 12 in one cycle.

DESCRIPTION: Coralla fragmentary, largest fragment about 8 cm in diameter, apparently sub-hemispherical to sub-pyriform.

Corallites sub-polygonal to sub-rounded, usually 5 or 6-sided, strongly radiating to parallel, uniform in size, 1.2 to 1.5 mm in diameter, sometimes slightly less. Walls thickened, usually about 0.2 to 0.3 mm in diameter, difficult to estimate because of broad-based septal spines, about 0.1 mm where the septal spines are poorly developed; walls often with very thin intermural spaces up to 0.1 mm thick, usually much thinner, filled with clear calcite; growth lamellae low-angled.

Tabulae comparatively thick, horizontal, sometimes straight, but more often made slightly concave by the upward inflection of their edges, occasionally slightly inclined, imperfect or incomplete, very often suspended from septal spines, spacing uniform, 30 to 38 per cm, usually about 33.

Mural pores circular, set in deep, funnel-shaped pits, constant diameter of about 0.2 mm, uniserial with regular spacing between 0.6 and 0.8 mm, usually placed in the centre of the faces of the corallites, occasionally alternately biserial in larger corallites. Pore plates invariably present.

Septal apparatus variably developed. When well developed consists of pointed, discrete, upward-directed septal spines often curved upwards, extending up to 0.3 mm into lumen, with an extremely variable basal width, arranged in highly irregular vertical columns with about 0.3 mm between each spine and up to 0.5 mm between each column, but as little as 0.1 mm apart where the spines are exceedingly slender. Where poorly developed they consist of broad-based tubercular projections appearing often as irregular swellings in the walls (Pl. XIV, fig. 1). Up to 12 septal spines in one cycle, usually about 6.

TYPE SPECIMEN: Holotype M.2927 — T.789-92, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 7 (rare), 11 (occasional), 27 (rare), Limestone Phase, Coopers Creek Formation. One other poorly preserved specimen (T. 782) from Loc. 7 is questionably referred to this species.

This species also occurs in the Kiln Member of the Bell Point Limestone, Waratah Bay.

REMARKS: The irregular, funnel-shaped depressions around the mural pores are a striking characteristic of this species. In longitudinal sections of the faces of the corallites these depressions appear as large irregular holes of greater diameter than the mural pores when the section contains less than half the thickness of the wall. In longitudinal sections at right angles to this (i.e. where the mural pores are represented merely by discontinuities of the wall) the wall between each mural pore usually only gradually expands from the opening to reach its full thickness approximately half way between pores. The isolated pieces of wall thus have a rhombic outline in section and so simulate broad backed septal spines or squamulae, particularly as wide-based septal spines invariably are mounted at the apices (Pl. XIV, fig. 3).

This species bears little relationship to *F. goldfussi* d'Orbigny, although Hill (1954b) has previously identified it as such from the Bell Point Limestone of the Devonian of Waratah Bay. It differs from *F. goldfussi* in the smaller diameter of the corallites, the closer spacing of the tabulae, the strong pitting of the mural pores which are larger and also usually uniserial, and also in the thickness of the walls and the nature of the septal apparatus (cf. Pl. XI, fig. 6-9 with Pl. XIV, fig. 1-3).

Much closer comparison can be drawn with *F. styriacus* Penecke 1893, a species from the Lower Devonian of Austria. *F. styriacus styriacus*, as described by Schouppé (1954b), has only very slightly larger corallites (1.4 to 1.8 mm in diameter) and similar variable development of the septal spines and wall thickness. The mural pores, also, bear a strong resemblance to those of *F. hillae* although they are more typically biserial. The greatest difference appears to be in the spacing of the tabulae, which in *F. styriacus* is highly variable—1.5 mm apart in places, while in others 2 to 3 per mm. In *F. hillae* they are closely and regularly spaced at about 3 to 6 per mm. Also the septal spines are typically horizontal and much more numerous in Penecke's species. Comparison can also be drawn with *F. singularis* Sokolov (Obut 1939, Pl. 3, fig. 9-10) a species virtually identical with *F. styriacus perforatus* Schouppé 1954. In passing it may be noted that all illustrations of *F. singularis* Sokolov, placed by Sokolov (1955) in *Squameofavosites* Chernyshev 1941, show the species to possess irregular, broad-based septal spines similar to those of *F. hillae*, rather than squamulae as the term is generally defined.

Le Maitre (1934, Pl. 9, fig. 6) has figured a specimen from the upper Lower Devonian limestone of Chaudéfond as *F. styriaca* (non *F. styriacus* Penecke ?) which is closely comparable with *F. hillae* in the spacing of the tabulae and the size of the corallites as well as the uniserial pores. However it appears to lack the characteristic septal spines and counter-sunk mural pores of *F. hillae*.

Favosites coactilis sp. nov.

(Pl. XII, fig. 3-4; Pl. XIV, fig. 4-6)

Favosites sp. Chapman 1914b, p. 315, Pl. 56, fig. 26.

Favosites forbesi Edwards and Haime, (*partim*) Chapman 1914, p. 308, Pl. 56, fig. 27 non Pl. 53, fig. 19.

Striatopora sp. Hill 1954b, p. 115, Pl. 9, fig. 28a-b.

DIAGNOSIS: Sub-digitate *Favosites* with corallites gently expanding in axial region, bending sharply to emerge normal to surface of corallum. Corallites typically unequal in size particularly in axial region, mature corallites averaging about 1.2 mm in diameter. In axial region walls comparatively thin, about 0.17 mm in

diameter but increasing to 0.5 mm distally. Tabulae about 14 per cm axially but more crowded distally with characteristic superior thickening of stereome; mural pores uniserial, about 0.2 mm in diameter and averaging 0.6 mm apart. Septal apparatus poorly developed axially but distally with small, upwardly directed septal spines.

DESCRIPTION: Corallum sub-cylindrical, branching into broad blunt bushy expansions that may become united by later overgrowths. Branches usually slightly less than 2 cm in diameter, largest amalgamated corallum fragmentary, measuring 7 x 5 x 3 cm.

Corallites gently expanding in axial region of corallum, usually bending sharply through 90° when leaving axial region to emerge at right angles to the surface of the corallum, sub-polygonal to rounded in distal regions where the corallite walls are thickened. Mature corallites 1 to 1.3 mm in diameter, normally about 1.2 mm, fairly constant in diameter, often with smaller corallites interspersed particularly in the axial regions of the corallum. Walls thick, 0.15 to 0.20 mm, averaging about 0.17 mm in the axial regions, expanding up to 0.5 mm distally. Intermural spaces fairly well defined and constant in diameter, usually 0.05 mm across.

Tabulae thickened distally by peculiar superior layer of stereome, usually slightly less than 0.1 mm thick, but up to 0.3 mm thick; in axial regions thickening much less apparent, as little as 0.02 mm. Where a thickened tabula meets the corallite wall adjacent to the lower part of a mural pore, the pore plate of that mural pore may also show similar thickening. Tabulae usually horizontal, flat, slightly convex or concave, sometimes inclined, occasionally inosculating or incomplete in which case the tabula may rest on the one lower for the best part of its length. Tabulae well spaced axially with about 14 per cm, becoming more crowded distally with 20 to 26 per cm, usually about 24 per cm. Occasionally tabulae suspended from septal spines.

Mural pores circular to slightly ovate, usually set in large depressions, typically 0.18 to 0.20 mm in height and 0.15 to 0.18 mm in width, mostly uniserial in the centre of the corallite faces but rarely irregularly biserial, averaging about 0.6 mm apart but between 0.5 and 0.9 mm. Pore plates usually present, often thickened.

Septal apparatus poorly developed in axial region, consisting of occasional low wide-based projections into the lumen. Distally better developed, where small, usually upward directed septal spines extend up to 0.12 mm into the lumen, about 0.8 mm wide at base and irregularly arranged in vertical columns up to 0.2 mm apart and up to about 16 in one cycle.

TYPE SPECIMENS: Holotype M.2949 — T.833-4. Paratype M.2950 — T.835. Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (rare), 11 (occasional), 15 (rare), 27 (occasional), Limestone Phase, Coopers Creek Formation; Loc. 43 (rare), 47 (common as moulds), 48 (rare), Boola Beds.

REMARKS: The thickening of the tabulae on their upper surfaces is a consistent character of this species. This type of thickening has already been described in certain North American favositids, viz. *Emmonsia radiata* (Rominger), *Favosites turbinata* Billings (Swann 1947) and *F. hamiltoniae expansa* Ross 1953.

[Swann (1947) followed by Ross (1953) are among the recent authors who have regarded *Favosites* as feminine in gender. Here the genus is treated as masculine, as the Greek suffix '—ites' appears to be solely masculine, its feminine equivalent being '—itis'. (See also Declaration 40 of the International Commission in Zoological Nomenclature, 1958.)]

The form of the corallum of this species, typically cylindrical and branching and then at times amalgamated, with the apparently concomitant distal thickening of the corallite walls and distal crowding of the tabulae, is characteristic of quite a number of species of *Favosites*, although such features are usually regarded as of generic merit and so such species are placed in the genus *Thamnopora*. Among the Australian species this type of growth is seen also in *F. grandiporus* Etheridge 1890 from the Lilydale Limestone. Of the species showing this type of growth *F. coactilis* is perhaps closest to the Middle Devonian *F. gracilia* Ross 1953 which, however, is a squamulate species. *F. coactilis* is closely related to *F. hillae* in corallite diameter, septal apparatus and size and distribution of the mural pores.

(Pl. XII, fig. 5-6)

DESCRIPTION: Corallum sub-hemispherical, with radius about 3 cm.

Tabulae moderately thick, 18 to 23 per cm, usually about 20 per cm; individual tabulae as distant as 1 mm, usually horizontal, sometimes inclined, flat to highly concave, rarely convex, occasionally inclined, rarely incomplete or suspended from septal spines. Occasionally ill-defined zones of closely spaced tabulae present.

Septal apparatus of small, thorn-shaped spines, usually with a slight upward

inclination and extending up to 0.2 mm into the lumen but usually less, with a base as much as 0.12 mm wide. Septal spines arranged in highly irregular vertical rows in which the spines are up to 0.3 mm apart. As many as 16 spines present in one cycle, but usually only about 8 visible.

FIGURED SPECIMEN: T. 822-3 from M. 2944, Loc. 27, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 16 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The two specimens from Tyers differ in a few minor respects from the descriptions of this species given by Jones (1937) and Hill and Jones (1940). The most noticeable of these is the size of the corallites which in the present form are about 1 mm in diameter, reaching a maximum of up to 1.2 mm. The usual diameter of the corallites in this species is between 1 and 2 mm. Jones does remark, however, that the corallite diameter is highly variable in *F. allani*. Other differences are in the ovate mural pores and shorter septal spines in the Tyers form.

The smaller corallite diameter suggests that the Tyers form is intermediate between *F. allani* and *F. regularis* Jones 1937 *non* Chapman 1921. It is possible, however, that *F. regularis* is in fact conspecific with *F. allani*.

Among overseas species *F. allani* is perhaps most closely allied to *F. punctatus* Boulier 1826 (Nicholson 1881, p. 19-20, Pl. 1, fig. 3a-c) from the Lower Devonian of Mayenne, a species with similar corallite diameter and spacing of tabulae. *F. punctatus* further is said to possess irregularly developed septal spines. The walls of this species however appear to be thinner, and the mural pores, although similarly distributed, are more often biserial and are apparently smaller.

One section (T. 822) shows corallites virtually lacking septal spines surrounding a damaged portion of the corallum. Again they do not appear at all well in T. 825, but this appears to be a function of the preservation.

Favosites sp. cf. *F. inosculans* Nicholson

(Pl. XV, fig. 1-2)

Cf. *Favosites?* *inosculans* Nicholson 1881, p. 20-1, Pl. 1, fig. 4-4a.

Cf. *Favosites inosculans* Nicholson, Le Maitre 1934, p. 169-70, Pl. 8, fig. 4-6; Kraicz 1935, p. 36-7, fig. 1, 3.

non Favosites inosculans Nicholson, Le Maitre 1931, p. 575, 7, Pl. 29, fig. 1-4. (cited Pl. 23, fig. 1-4).

non Favosites inosculans Nicholson, Le Maitre 1937, p. 113-4, Pl. 8, fig. 1-3.

non Favosites inosculans Nicholson, Flügel 1953, p. 65, 68 (*vide* Shouppé 1954b, p. 28).

DESCRIPTION: Corallum apparently hemispherical, known only from a single fragment.

Corallites gently diverging, lateral corallites becoming curved distally as they emerge normal to the surface of the corallum. Corallites rounded, up to 6-sided, fairly variable in size, up to 0.55 mm in diameter, usually about 0.4 to 0.5 mm, in transverse section up to 6 may appear interconnected through the large mural pores. Walls comparatively thick, up to 0.12 mm in diameter, usually about 0.08 mm, intermural spaces consistent in thickness where visible, about 0.02 mm thick.

Tabulae comparatively thick, very irregular in distribution, 1.5 to 0.1 mm apart, about 20 per cm, flat or sometimes concave, horizontal or more often inclined, sometimes steeply, rarely incomplete.

Mural pores usually ovate to circular, comparatively large, usually about 0.2 mm

by about 0.15 mm in a single row in the centre of the corallite face, with longest dimension parallel to the growth direction, 0.5 to 0.8 mm apart, usually about 0.6 mm. Mural pores with moderate pitting (i.e. depressed), which together with slight flexing of corallite walls gives the irregular longitudinal sections.

Septal apparatus of small linguiform squamulae, horizontal or with a slight upward inclination, thickening toward the base, where in longitudinal section they are about 0.02 mm thick, extending up to 0.1 mm into the lumen with width constant for their entire length, even expanding to reach their greatest width half way to the rounded distal end, up to 6 in one cycle, usually about 3 visible in one corallite, often obscured by secondary deposits of calcite.

FIGURED SPECIMEN AND OCCURRENCE: M.2947 — T.826-7, Loc. 19, Limestone Phase, Coopers Creek Formation.

REMARKS: There exists a certain doubt as to the nature of *F. inosculans*. For example Le Maitre (1931, 34, 37) has illustrated three different forms as this species, of which the second appears to be conspecific with Nicholson's species. The first is closely comparable with *F. squamuliferus* forma *nitidus* Chapman while the third is probably conspecific with *F. grandiporus* Etheridge 1890 (*vide* Philip 1960a). One's interpretation of these specimens is not helped by Le Maitre's descriptions which are identical in the first two of these references although very different specimens are illustrated.

The specimen figured by Le Maitre (1934) agrees with Nicholson's description of the species. It should be noted, however, that Nicholson remarks on the absence of septal spines (as does also Le Maitre) in this species but what appear to be small, flattened, linguiform squamulae, very similar to those described in the Tyers form, are present in Le Maitre's fig. 5. Le Maitre (1937) does mention the presence of occasional septal spines in this species, but the specimen figured is not *F. inosculans*.

The salient character of the species, the inosculating nature of the corallite walls in transverse sections, is apparent in the specimen from Tyers. Hill and Jones (1940) have considered this inosculating appearance to be due to the fact that the mural pores are often at the angles of the corallites, so that three corallites may communicate. Rather it would appear to be due to the fact that the comparatively large mural pores are at the same height in adjacent corallites. The form from Tyers differs from *F. inosculans* in the greater separation of the mural pores which are about twice the distance apart and in the more distant, irregular tabulae. Should more material come to hand and establish that these differences are consistent, then it would be wise to recognize our Australian form as a separate subspecies.

Comparison can be drawn between *F. inosculans* Nich. and *F. favisitoides* (Ozaki 1934), the type species of *Sapporipora* Ozaki 1934, from the Silurian of Korea. They are similar in the size of corallites, spacing of the tabulae and the size and distribution of mural pores, although *F. favisitoides* does not possess the inosculating character of the corallite walls in transverse section. Further, the walls are thinner in *F. favisitoides* which also appears to possess a specialized mode of increase.

Favosites macilentus sp. nov.

(Pl. XIV, fig. 7-8)

DIAGNOSIS: Corallum discoidal; small corallites of variable size averaging 0.5 mm in diameter; walls averaging 0.1 mm in thickness; tabulae about 30 per cm; mural pores ovate, greatest dimension 0.16 mm, widely biserial at the edge of the

faces on which they occur, about 1.7 mm apart in their respective columns. Septal apparatus of occasional, thin, horizontal septal spines.

DESCRIPTION: Largest corallum discoidal, up to 3 cm in diameter, 1.5 cm high.

Corallites subpolygonal to rounded, parallel to slightly radiating, variable in size, irregularly dimorphic, or with clusters of larger corallites up to 1 mm in diameter interposed with smaller corallites, average diameter about 0.5 mm. Larger corallites 6 or 7-sided, smaller usually 5-sided. Walls thickened around larger corallites, up to 0.2 mm in diameter, usually about 0.1 mm, sometimes less. Intermural spaces fairly persistent, up to about 0.04 mm in diameter, in longitudinal sections often showing thickening at similar heights in adjacent corallites.

Tabulae moderately thin, horizontal, flat or slightly concave or convex, rarely irregularly inosculating, in places suspended from septal spines, spaced uniformly between 28 and 33 per cm, and up to 0.6 mm between individual tabulae.

Mural pores ovate with longest dimension in direction of growth, usually between 0.15 and 0.17 mm by about 0.1 to 0.12 mm, widely biserial, alternate, at the edges of the faces of which they occur, averaging about 1.7 mm apart in their respective columns.

Septal apparatus of thin elongate septal spines, with horizontal or slightly upward inclination, circular in cross-section, extending up to 0.15 mm into the lumen, about 0.4 mm in width which remains constant to the rounded distal extremity. As many as 6 septal spines in one cycle, usually only very few visible in transverse sections. Apparently irregularly arranged within the corallites.

TYPE SPECIMEN: Holotype M.2956—T.850-3, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (occasional), 27 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: This species, in the location of the mural pores towards the edges of the faces of the corallites, recalls *F. asper* d'Orb., the type species of *Paleofavosites* which includes species differing from *F. gothlandicus* Lamarck merely in this respect. This, as with other characters which have been used to split the genus *Favosites*, is an extremely arbitrary feature for even in *F. asper* itself there is present a wide variation in the location of the mural pores (Jones 1936).

However, a distinction should be drawn between the mural pores in *F. macilentus* and *F. asper*. In *F. macilentus* the mural pores, although at the extreme edge of the faces on which they occur, never are located at the corners of the corallites so that more than two are in communication.

F. macilentus differs from *F. asper* and related species in the small size of the corallites, the spacing of the tabulae and the septal apparatus. It bears very little relation to any local or overseas species. '*Paleofavosites*' *arcticus* Poulson 1941, from the Silurian of North Greenland, has similar corallite diameter but much closer tabulae.

Favosites sp.

(Pl. XIII, fig. 3-4)

DESCRIPTION: Corallum apparently sub-hemispherical, known only from fragments.

Corallites polygonal, usually 5 or 6-sided, parallel or gently expanding, uniform in size, averaging 1.2 mm with occasional smaller corallites present. Walls comparatively thin, up to 0.08 mm, usually about 0.06. Thin linear intermural spaces often present between the corallite walls.

Tabulae moderately thick, usually flat and horizontal, sometimes inclined or incomplete, occasionally inosculating, regularly spaced between 25 to 30 per cm, usually about 28.

Mural pores circular, diameter up to 0·23 mm, usually 0·18 mm, closely spaced, usually irregularly biserial or triserial, very occasionally uniserial.

Septal apparatus absent.

FIGURED SPECIMEN: T.1055-6 from M.3009, Loc. 27, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation. The specimen from Loc. 11 is poorly preserved and infilled with a layer of drusy calcite but undoubtedly is conspecific with this form.

REMARKS: This species of *Favosites* differs from other Australian species of comparable corallite diameter and tabulae spacing (*F. moonbiensis*, *F. allani*, *F. squamuliferus*) in the character of the mural pores. It is, however, almost identical in every respect with the species identified as *F. hisingeri* Edwards and Haime by Chernyshev (1951) from the Upper Silurian of the Kuznetsk Basin. Although Chernyshev describes the septal spines as 'very well developed and upwardly directed' they are not visible in his figures. *F. hisingeri* is a species characterized by strongly developed septal spines.

Favosites moonbiensis Etheridge

(Pl. XII, fig. 7-8; Pl. XXI, fig. 4)

Favosites basaltica (Gold.) var. *moonbiensis* Etheridge 1899a, p. 164-5, Pl. 24, fig. 1-2, Pl. 29, fig. 2; Jones 1937, p. 96, Pl. 15, fig. 1-2.

Favosites basalticus (Gold.) var. *moonbiensis* Etheridge, Jones 1944, p. 34.

DESCRIPTION: Corallum flattened, sub-hemispherical to discoidal, largest corallum in collection with diameter of 10 cm. Basal epitheca present.

Corallites sub-polygonal, with rounded corners, usually 6-sided, gently radiating to parallel, uniform in size with an average diameter of about 1·2 mm but up to 1·5 mm; occasionally smaller corallites are present. Walls moderately thick, 0·08 to 0·20 mm at the corners, usually slightly in excess of 0·1 mm; intermural spaces usually present at the corners of the corallites, and extending a little distance from the corners in between the corallite walls, giving rise to poorly defined 'stellate' structures at the corners of the corallites, ill-defined in longitudinal sections.

Tabulae thin, horizontal, usually slightly convex, sometimes flat, very rarely concave, occasionally inclined, incomplete or imperfect, very rarely inosculating. Spacing of tabulae 24 to 30 per cm, usually about 28, individual tabulae up to 0·8 mm apart; ill-defined zones in which the tabulae are closer are sometimes present.

Mural pores circular to very slightly ovate with longest dimension parallel to the direction of growth, diameter 0·19 to 0·25 mm, usually slightly in excess of 0·2 mm, typically irregularly uniserial toward the centres of the corallite faces, 0·5 to 0·8 mm apart, usually about 0·65 mm, very rarely widely biserial opposite or alternate, in which case the mural pores are very much toward the edges of the corallite faces, although the spacing remains the same. Mural pores set in a very slight depression, occasionally with a slight thickening of the wall above the mural pores. Pore plates usually absent.

Septal apparatus absent.

FIGURED SPECIMENS: T.798, 800 from M.2932, Loc. 48; M.2940, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 47 (rare), 48 (abundant), 49 (rare), Boola Beds.

Prior to this, *F. moonbiensis* has been recorded from rocks of Middle Devonian age.

REMARKS: The writer (1960a), on the basis of marked similarity between this species and *F. squamuliferus* forma *bryani*, has suggested that *F. moonbiensis* represents merely a modified form of *F. squamuliferus* in which the septal apparatus is absent. This was considered to have been caused by environmental differences as *F. moonbiensis* is confined to the mudstone facies of the Boola Beds whereas the various formae of *F. squamuliferus* occur virtually exclusively in the limestone facies of the Coopers Creek Formation. It should be noted, however, that *F. moonbiensis* does not show the extreme variation of *F. squamuliferus*, but can be defined within strict limits of variation.

Etheridge (1899a) has already noted the intermural spaces at the corners of the corallites in this species. They are apparent in his Pl. 24, fig. 2 as well as in the illustration of this species given by Jones. Of them, Etheridge (p. 165) states—'At the angle of a corallite a light clear spot is visible in the wall substance, but on vertical examination there is not the slightest trace of any structure after the nature of an acanthopore'. These light spots may be intermural spaces or can be caused by bleaching of the stereome of corallites in the vicinity of intermural spaces.

F. moonbiensis is closely comparable with *F. proasteriscus* Charlesworth 1914 from the Lower Devonian of the Carnic Alps and *F. interstinctus* Regnéll from the Siluro-Devonian of Chöl-tagh, Eastern Tien-shan. Both these species possess similar intermural deposits.

Favosites squamuliferus Etheridge

Favosites squamulifera Etheridge 1899a, p. 166-7, Pl. 38, fig. 4-5.

Favosites squamuliferus Etheridge, Philip 1960a.

The writer (1960a), on the basis of a detailed study of the squamulate favositids occurring in the Limestone Phase of the Coopers Creek Formation in this area, concluded that, of the 13 specific names proposed for Australian species of squamulate favositids, 2 alone could be regarded as valid species. These were *F. grandiporus* Etheridge 1890, known only from the Lilydale Limestone, and *F. squamuliferus* Etheridge 1899. *F. squamuliferus* was interpreted as a species exhibiting particularly gross variation and so was separated into 8 arbitrarily chosen formae. For completeness brief diagnoses and the occurrences of the various formae of *F. squamuliferus* are given here. Full synonymies and descriptions are given in the paper mentioned above.

To the list of 11 overseas species given by the writer which fall within the morphological range exhibited by *F. squamuliferus*, a further Russian species may be added. It is *Emmonsia taltiensis* Yanet in Sokolov 1955, Pl. 14, fig. 6-7, Middle Devonian, Urals. This form is indistinguishable from *F. squamuliferus* forma *bryani* in which the tabulae are closely spaced.

F. squamuliferus forma *bryani* (a) Jones

(Pl. XIII, fig. 1-2)

DIAGNOSIS: Corallum massive, corallites polyhedral averaging greater than 0.8 mm in diameter and usually less than 1.5 mm; mural pores uniserial, circular to slightly ovate, between 0.15 and 0.35 mm in diameter and between 0.3 and 0.8 mm apart. Squamulae highly variable, horizontal or upwardly directed, developed either

back-to-back in adjacent corallites above the mural pores or isolated. Slender septal spines may also be present.

FIGURED SPECIMENS: T.891 from M.2973, Loc. 11; T.917 from M.2982, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 1 (rare), 5 (occasional), 6 (rare), 7 (rare), 9 (rare), 10 (rare), 11 (abundant), 13 (rare), 14 (rare), 15 (occasional), 16 (occasional), 18 (rare), 19 (occasional), 22 (rare), 24 (rare), 26 (rare), 27 (occasional), Limestone Phase, Coopers Creek Formation; Loc. 33 (rare), Conglomerate Phase, Coopers Creek Formation.

F. squamuliferus forma nitidus (β) Chapman

DIAGNOSIS: *F. squamuliferus* with average corallite diameter between 0.8 and 0.5 mm.

OCCURRENCE: Loc. 1 (occasional), 2 (rare), 3 (rare), 5 (occasional), 7 (occasional), 8 (rare), 9 (rare), 10 (rare), 11 (abundant), 12 (rare), 13 (occasional), 15 (rare), 16 (rare), 19 (occasional), 20 (occasional), 23 (occasional), 24 (rare), 26 (rare), 27 (common), Limestone Phase, Coopers Creek Formation; Loc. 47 (rare), Boola Beds.

F. squamuliferus forma stilliformis (γ) Chapman

DIAGNOSIS: *F. squamuliferus* with corallite diameter less than 0.5 mm.

OCCURRENCE: Loc. 1 (rare), 3 (rare), 19 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation.

F. squamuliferus forma stelliformis (γ) Chapman

(Pl. XV, fig. 3-4)

Cannapora australis Chapman 1907, p. 76, Pl. 3, fig. 6-7; Pl. 8, fig. 17-18.

DIAGNOSIS: *F. squamuliferus* with small corallite diameter and sub-ceroid growth.

FIGURED SPECIMEN: T. 937-8 from M. 2989, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (occasional), 20 (rare), 23 (rare), 27 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: This species was described by Chapman from the limestones along the Tyers River.

F. squamuliferus forma ovatiporus (ϵ) Hill and Jones

DIAGNOSIS: *F. squamuliferus* with large, ovate mural pores, reduced squamulae and well spaced tabulae.

OCCURRENCE: Loc. 11 (occasional), Limestone Phase, Coopers Creek Formation.

F. squamuliferus forma ζ Philip

DIAGNOSIS: *F. squamuliferus* with small distant mural pores, reduced squamulae and well spaced tabulae.

OCCURRENCE: Loc. 20 (rare), Limestone Phase, Coopers Creek Formation.

F. squamuliferus forma η Philip

DIAGNOSIS: *F. squamuliferus* with exceedingly thin walls.

OCCURRENCE: Loc. 11 (rare), Limestone Phase, Coopers Creek Formation.

F. squamuliferus forma θ Philip

DIAGNOSIS: Sub-digitate thick-walled *F. squamuliferus* with irregularly spaced mural pores and reduced squamulae.

OCCURRENCE: Loc. 3 (common), 11 (occasional), 15 (occasional), 19 (rare), 20 (common), Limestone Phase, Coopers Creek Formation.

F. squamuliferus Etheridge (?)

(Pl. XIII, fig. 5-6)

Favosites (*Emmonsia*) *spinigera* Chapman 1921, p. 214-5, Pl. 9, fig. 21.
non *Favosites spinigera* Hall 1879, p. 108, Pl. 4, fig. 1-5.

DESCRIPTION: Corallum known only from fragments but apparently sub-hemispherical.

Corallites polygonal, variable in size, up to 2.2 mm, but averaging 1.4 mm, usually 6-sided. Walls reaching 0.3 mm in diameter but usually slightly less than 0.1 mm, slightly thickened at the corners, often with thin, clear, linear intermural spaces.

Tabulae about 20 per cm but highly variable in spacing, usually incomplete, suspended or resting on a lower tabula, often highly curved or contorted.

Mural pores circular, uniform in size, averaging 0.2 mm in diameter, uniserial toward the middle of the corallite faces or widely biserial; pore plates usually present.

Septal apparatus of strongly developed squamulae and very occasional, thin, discrete septal spines. Squamulae in transverse sections up to 0.2 mm in width at their base, often expanding along their length and distally rounded. In longitudinal sections triangular, up to 0.25 mm thick at their base, but usually less, strongly tapered, usually horizontal or upwardly directed, in places extending over half way across the lumen, as close as 0.4 mm apart in longitudinal sections and as many as 5 visible in the one corallite in transverse sections. Squamulae usually occurring isolated, but may be back-to-back above the mural pores.

FIGURED SPECIMEN: T.1043-4 from M.3007, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (rare), 11 (rare), 22 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The writer (1960a) has placed *F. spinigera* Chapman 1921 in the synonymy of *F. squamuliferus* forma *bryani* Jones. Since then there has come to light in the Chapman collection purchased by the Melbourne University Geology Department two sections of *Favosites* from Deep Creek, Gippsland. One of these (now catalogued T. 1203) labelled merely 'Deep Creek, 7 miles SE. of Walhalla' is undoubtedly from the misplaced type of *F. spinigera* which Chapman described from this locality. The only difference between this slide (Pl. XIII, fig. 7) and the form from Tyers is in the squamulae which are less crowded, not so wide and so more rounded in cross-section, which allows the tabulae to appear more complete in

longitudinal section. Thus Chapman's specimen is intermediate between our present form and *F. squamuliferus* forma *bryani*.

Whether this form is merely a further forma of *F. squamuliferus* characterized by exceedingly strongly developed squamulae or actually constitutes a separate species, it is impossible to say from the material available. The specimens from Loc. 3 and 22 are so poorly preserved that they throw little light on the problem. In view of the gross variation shown by *F. bryani*, however, the former is the more likely.

Chapman's other slide (T. 1202) from Deep Creek is of *F. squamuliferus* forma *nitidus* Chapman.

'Emmonsia' sp. affin. 'E.' fusta Greenc

(Pl. XIII, fig. 8)

Affin. *Favosites fustus* Greene 1906, p. 37, Pl. 9, fig. 3-4.

Affin. *Emmonsia fusta* Green, Stumm 1949a, 'Tabulata', card 203.

DESCRIPTION: Corallum known from one section only, small, subpyriform, attached to a crinoid stem.

Corallites about 2 mm in diameter, apparently polygonal, walls usually slightly less than 0.2 mm thick.

No tabulae observed crossing lumen, apparently all broken as specimen now filled with limestone matrix. Mural pores small, circular, 0.12 to 0.22 mm in diameter, averaging about 0.15 mm, irregularly biserial or triserial.

Septal apparatus of thin-based, upwardly directed squamulae extending up to 1 mm into lumen but commonly less, slightly tapered in longitudinal section, as close as 0.2 mm apart vertically; relation to mural pores unknown.

FIGURED SPECIMEN AND OCCURRENCE: T.1052 from M.3008, Loc. 3, Limestone Phase, Coopers Creek Formation.

REMARKS: Of the species generally included in the polyphyletic grouping *Emmonsia* E. and H., this form, as far as can be interpreted from this single fragmentary specimen, bears closest resemblance to '*Emmonsia*' *fusta* Greene from the Middle Devonian of Ohio.

Genus Alveolites Lamarck 1801

Alveolites sp. affin. A. taenioformis Schlüter

(Pl. XV, fig. 5)

Affin. *Alveolites taenioformis* Schlüter 1899, p. 121; Lecompte 1939, p. 55-6, Pl. 8, fig. 3-4; Stasinska 1958, p. 214-6, Pl. 25, fig. 1-2; Pl. 26 (*cum. syn.*).

DESCRIPTION: Corallum laminar, composed of irregular layers up to 4 mm thick in which the corallites are more or less horizontal.

Corallites sub-triangular to sub-lunate averaging slightly less than 0.2 mm in height and about 0.4 mm in width; most sections are oblique so the corallites appear with a greater width. Walls moderately thick, usually 0.08 mm in diameter but reaching up to 0.12 mm in places.

Tabulae straight, irregularly spaced, and not common, in places they may be as close as 0.2 mm apart but usually much more distant. Mural pores circular to slightly ovate averaging 0.1 mm in diameter and about 0.45 mm apart, contained in the corners of the corallites.

Septal spines absent.

FIGURED SPECIMEN: T.917 from M.2982, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (rare), 11 (rare), 15 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: This form, known only from 3 fragmentary specimens, is strikingly similar to the Couvinian and Lower Givetian species *Alveolites taenioformis* Schlüter. It differs from that species essentially in the more irregular spacing of the tabulae and in the mural pores, which are slightly larger and closer. If these differences prove to be consistent in the light of further material, then it would be best to separate the Tyers form from Schlüter's species. The material to hand is not sufficient on which to base a new species or sub-species.

Alveolites sp.

(Pl. XV, fig. 6)

DESCRIPTION: Corallum apparently an irregular hemispherical mass at least 3 cm in diameter.

Corallites sub-lunate to sub-polygonal 5 or 6-sided, height constant at 0.3 mm, usually about 0.4 mm wide, but up to 0.6 mm. Walls usually slightly less than 0.05 mm, but up to 0.08 mm thick.

Tabulae moderately thick, slightly concave, distant, usually about 0.8 mm apart but may be more crowded where the corallum is damaged. Mural pores ovate with longest dimension in the direction of growth, 0.19 mm by 0.17 mm, spacing not known, usually situated in the angles of the corallites when they are sub-lunate in shape, but may be in the centre of the faces where corallites are sub-polygonal.

Thin septal spines occasionally present.

FIGURED SPECIMEN AND OCCURRENCE: T.1062, Loc. 27, Limestone Phase, Coopers Creek Formation. A further poorly preserved specimen from Loc. 15 also probably belongs to this species.

REMARKS: This species is apparently new, but the material is such that positive identification is impossible.

Genus *Thamnopora* Steininger 1831

Thamnopora alterivalis (Chapman)

(Pl. XVI, fig. 6)

Pachypora alterivalis Chapman 1914, p. 309, Pl. 57, fig. 28-29.

Thamnopora alterivalis (Chapman) Hill 1950, p. 152-3, Pl. 8, fig. 28a-b.

DESCRIPTION: Corallum digitate, cylindrical, 8 mm in diameter or slightly greater, largest specimen 30 mm long.

Corallites usually 6-sided and polygonal but rounded by thickening of walls, fairly uniform in size, attaining 0.6 mm in diameter axially, and increasing to as much as 0.8 mm distally. Corallites expanding gently from the axial region and sharply inflected near the surface of the corallum to emerge normal to the surface; zone normal to the surface up to 1.5 mm wide. Walls usually less than 0.2 mm in width in axial regions, expanding to 0.4 mm distally, with thick primary walls and irregular intermural spaces.

Tabulae thick, flat to strongly curved, usually inclined, spacing averaging about 1 mm apart in axial region, more crowded distally where 8 may be present in a distance of 3 mm.

Mural pores circular, averaging 0.2 mm in diameter, about 0.8 mm apart and situated toward the centre of the corallite faces.

Septal spines absent.

FIGURED SPECIMEN: T.1081, Loc. 27, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 16 (rare), 27 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: There can be little doubt that the specimens described here as *T. alterivalis* are conspecific with Chapman's species. However, the corallum is in general somewhat larger than in the type specimen and the material described by Hill (1950) from the Middle Devonian of Buchan. Hill has pointed to the very close comparison which can be drawn between *T. alterivalis* and *T. reticulata* (de Blainville) from the Middle and Upper Devonian of Europe. The only apparent difference between these species is that *T. alterivalis* possesses slightly smaller corallites and very slightly more distant mural pores.

One specimen from Loc. 27 agrees completely with the characters of *T. alterivalis* except that no tabulae are present. Smith (1945, p. 61) has noted, however, that 'specimens of *Thamnopora* are often found in which the tabulae have perished'.

Thamnopora boloniensis (Gosselet)

(Pl. XVI, fig. 2-4)

Madreporites cristatus Blumenbach 1803, p. 25-6, Pl. 3, fig. 12.

Favosites dubia Edwards and Haime 1851, p. 243-4.

Favosites boloniensis Gosselet 1877, p. 271.

Thamnopora boloniensis (Gosselet) Lecompte 1939, p. 122-8, Pl. 17; Pl. 18, fig. 1-6; Kropfisch and Schouppé 1953, p. 91-5, fig. 1 (*cum syn.*); Hill 1954a, p. 30-31, Pl. 2, fig. 16-18; Stasinska 1958, p. 198-200, Pl. 9-11.

DESCRIPTION: Corallum digitate, cylindrical, dichotomously branching, 9 to 10 mm in diameter, largest collected about 6 cm long.

Corallites basically polygonal but strongly thickened, so the calices are rounded; not uniform in size but up to 1 mm in diameter axially and attaining 2.4 mm in diameter distally. Corallites gently curving from the axial region to open at about an angle of 45° to the surface of the corallum. Walls with strongly developed primary walls, thickened to reach a diameter of 0.2 mm or more in the axial region and expanding gradually to reach a diameter of 0.8 mm distally.

Tabulae thin, straight, usually inclined, as close as 0.6 mm apart, usually about 5 per cm, apparently confined to the axial region. Mural pores circular to ovate with longest dimension parallel to the growth direction of the corallites; when circular averaging about 0.22 mm but as small as 0.16 mm in diameter, arranged in an irregular series toward the middle of the faces of the corallites, as close as 0.6 mm, but usually about 0.9 mm apart.

Septal spines absent.

FIGURED SPECIMENS AND OCCURRENCE: T.1067-8 from M.3010, Loc. 11, Limestone Phase, Coopers Creek Formation (occasional); T.1073, Loc. 51, Boola Beds (rare).

REMARKS: The specimens from Tyers differ in no essential feature from the descriptions of this species given by Lecompte (1939), Schouppé (1953) and Stasinska (1958). The only slight differences which could be pointed to are firstly, that the tabulae are less frequent and more regular in the Tyers form and secondly,

that the walls are slightly more thickened distally. In regard to this last point it should be noted that the single specimen from the mudstone facies of the Boola Beds shows greater thickening of the walls than do the limestone specimens. *T. boloniensis* ranges from lower Middle Devonian through into the Upper Devonian in various parts of Europe. It has also been described from the Devonian of Western Australia by Hill (1954a).

Among Eastern Australian species *T. boloniensis* perhaps resembles most closely the Middle Devonian *T. tumulosa* Hill 1950, a species which possesses, however, low septal ridges in the calices, as well as occasional septal spines. As *T. tumulosa* also shows dilation of the walls throughout the corallum, it is intermediate between *Thamnopora* and *Striatopora*, similar to the Silurian species *T. vaigacensis* Chernyshev 1938.



FIG. 2—*Natalophyllum callidum* sp. nov. Figure showing the shape of the corallites in the distally thickened portion of the corallum; walls white. From a polished section of the holotype M. 3015. $\times 15$.

Genus *Natalophyllum* Raduguin 1938

(= *Plagiopora* Gürich 1896 = *Scoliopora* Lang, Smith & Thomas 1940)

Natalophyllum callidum sp. nov.

(Pl. XVI, fig. 1, 5; Fig. 2)

? *Thamnopora* sp. Hill 1954b, p. 114, Pl. 9, fig. 27a-c.

DIAGNOSIS: *Natalophyllum* with a generally digitate corallum about 1 cm in diameter; corallites averaging 0.25 mm in diameter axially with walls 0.08 mm thick, strongly meandroid distally with walls thickened to 0.3 mm; tabulae strong,

about 8 per cm; mural pores ovate to circular, about 0.12 mm in diameter, spaced about 0.9 mm apart axially, averaging 0.4 mm apart distally. Septal spines absent.

DESCRIPTION: Corallum usually cylindrical, digitate, about 1 cm in diameter, largest in collection 4 cm long. One specimen with sub-pyriform corallum 2.5 cm high and 2 cm wide.

Corallites axially sub-rounded to slightly meandroid, fairly uniform in size, averaging 0.25 mm in diameter but reaching up to 0.4 mm. In digitate coralla the corallites bend sharply on leaving the axial zone and are normal to the surface of the corallum for a considerable distance before reaching it. In the sub-pyriform corallum the corallites diverge gently from a poorly defined axial region without the sharp change of growth direction. Distally corallites strongly meandroid with lumen diameter approximately 0.15 mm by as much as 0.6 mm; the meandroid shape probably due to the large mural pores which connect the corallites and so appear as channels through the thickened stereome of the walls. Wall thickness averaging 0.08 mm in axial region, expanding to 0.3 mm distally.

Tabulae strong, flat, horizontal or inclined, in places concave or strongly curved, irregularly spaced, as close as 0.15 mm, usually about 8 per cm but often less. Mural pores strongly ovate to almost circular, as large as 0.2 mm by 0.1 mm in the ovate pores where the longest dimension is parallel to the growth direction, more circular pores averaging 0.12 mm in diameter, in axial region as close as 0.6 mm apart but averaging 0.9 mm, distally closer averaging about 0.4 mm apart; in a single series at the centre of the corallite faces.

Septal spines absent.

TYPE AND FIGURED SPECIMENS: Holotype M.3011, T.1074-5, Loc. 20; T.830, Loc. 15, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 15 (rare), 20 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: In placing this species in the genus *Natalophyllum* Raduguin 1938 I have relied entirely on Sokolov's (1955) interpretation of the genus as Raduguin's original description is unavailable to me. *N. callidum* is very close to the species *N. huangi* Sokolov 1955 (Pl. 37, fig. 1-3); the only differences at all apparent are the smaller corallite diameter and larger mural pores of *N. callidum*. The genus *Natalophyllum*, as employed by Sokolov, clearly is extremely close to *Alveolites denticulatus* Edwards and Haime, the type species of *Scoliopora* Lang, Smith and Thomas 1940. Sokolov (p. 192) gives as the features by which the genera may be distinguished the thicker walls in the axial zone of *Natalophyllum* which show 'wall seams' (as do also Lecompte's (1939), Pl. 20, fig. 2, 3 of *Scoliopora denticulata*), the larger mural pores of *Scoliopora* and its better developed septal spines. As it appears neither useful nor even practicable to separate the two genera, it follows that *Natalophyllum* should replace the generic name *Scoliopora* which was proposed to replace the homonym *Plagiopora* Gürich 1896.

The holotype of *N. callidum*, in common with other species of *Natalophyllum*, possesses a digitate corallum, with sharp inflection of the corallites as they leave the axial zone, distal thickening of the corallite walls and the meandroid appearance of the corallites towards the surface of the corallum. Another specimen (Pl. XVI, fig. 5), although agreeing in all respects with the internal measurements of the holotype, has a sub-pyriform corallum in which the corallites are gently expanding. This suggests that the shape and growth of the corallum was variable in *N. callidum*.

Besides the growth of the corallum, the other feature which is usually regarded as a generic character in *Natalophyllum* is the meandroid appearance of the corallites toward the surface of the corallum. This, at least in *N. callidum*, is due to an abundance of comparatively large mural pores in the distal regions, so that tunnels are formed through the stereome of the thickened corallite walls of diameter comparable with that of the lumen diameter. I would regard the wall structure of greater taxonomic importance than the features mentioned above. As far as can be said from the illustrations of various species of *Natalophyllum*, the primary corallite walls are well developed in the axial region but are not at all apparent in the distally thickened portions of the corallum. This type of wall structure allies the genus to *Coenites* and quickly distinguishes it from *Thamnopora*.

Hill (1954b) has described a specimen from the Bell Point Limestone, Waratah Bay, in all probability conspecific with *N. callidum*. In that specimen Hill has taken the channels connecting the corallites in the distally thickened portions of the corallum to be possibly the work of boring organisms. Here they are regarded as mural pores.

Genus *Coenites* Eichwald 1829

Cladopora Hall 1851 has generally been regarded as a synonym of *Coenites* Eichwald 1829 [Hennig 1906; Smith 1933 (*vide* Lecompte 1939, p. 76); Hill and Stumm 1956]. Certain recent authors have maintained that *Cladopora* is a discrete genus (Lecompte 1936, 1952; Stumm 1949; Sokolov 1955; Stasinska 1958). The basis for this remains obscure as there is a whole gradation of species between those clearly allied to *Cladopora seriata* Hall and those comparable with *Coenites juniperinus* Eichwald, including species with foliar coralla not closely comparable to either type species. However, in the description of this fauna, it is convenient to distinguish between such species on the basis of the shape of the calices and for this reason *Cladopora* Hall is regarded as a subgenus of *Coenites*. This in no way is meant to imply any belief that the two are generically separate; the name is used merely as a morphological subgenus. It could be that *Cladopora* could be usefully used as a genomorph of *Coenites*, but it has yet to be established that the differences, primarily in the shape of the calices, may be developed in different lineages of *Coenites*. Sokolov (1955) and Stasinska (1958) go as far as to place *Cladopora* in the 'sub-order' Thamnoporina and *Coenites* in the 'sub-order' Alveolitina on the basis of the shape of the calices, a procedure which further highlights the artificial nature of Sokolov's classification.

Mention should be made of the Australian genus *Vetofistula* Etheridge 1917 based on *Vetofistula mirabilis* Etheridge 1917 from the Middle Devonian of Reid's Gap, Queensland. This genus was described by Etheridge as a bryozoan of uncertain affinities, but undoubtedly is based on a species of *Cladopora*.

Subgenus *Coenites* Eichwald 1829

DIAGNOSIS: Corallum digitate to laminar or massive in which case it is built up of successive layers. Sharply defined axial or median zone of the corallum in which the walls of the corallites are but slightly thickened and in which the primary walls of the corallites may sometimes be visible. Away from the median zone the walls become strongly thickened and the primary walls no longer discernible. Calices alveoliteoid. Mural pores and tabulae usually rare. Septa occasionally present in the calices.

***Coenites (Coenites) planifolium* sp. nov.**

(Pl. XVII, fig. 1-4; Pl. XXI, fig. 2)

DIAGNOSIS: *Coenites* with thin, flat coralla averaging less than 2 mm in thickness with well developed median zone of slightly thickened corallites averaging 0.2 mm in diameter, and diverging from the median zone at an angle of 30°. Walls increasing to 0.8 mm thick at the surface where the calices are narrow and slit-like, up to 0.5 mm wide and strongly crescent-shaped. Tabulae irregularly developed; mural pores 0.8 mm in diameter; septal apparatus lacking.

DESCRIPTION: Corallum foliar, forming thin sheets up to 5 cm in longest direction, averaging 2 mm thick, in places reaching 4 mm, usually flat, sometimes slightly flexed; with well developed median zone of small, thin-walled corallites, 2 to 3 corallites thick, and from which the corallites diverge outwards to both surfaces of the corallum.

Corallites medially small, fairly uniform in diameter, typically rounded with slight thickening of the walls, averaging slightly less than 0.2 mm in diameter with walls of 0.04 mm thick. Corallites diverge sharply from the median zone at an angle of 30° to it, and this growth direction is maintained till the corallites emerge. In these longitudinal sections the lumen diameter decreases slowly from the median region as the corallites become progressively more crescent-shaped. Walls increasing to 0.8 mm thick distally with no primary walls present although the stereome is fibrous with a marked preferred orientation of the calcite fibres. At the surface the calices are strongly crescent-shaped, as much as 0.5 mm wide and less than 0.1 mm high.

Tabulae irregularly developed, apparently absent in places, thin, flat and normal to growth direction of the corallites. Mural pores circular to slightly ovate, averaging 0.08 mm in diameter and usually about 0.7 mm apart, but fairly irregularly spaced; tabulae and mural pores confined to median zone of corallum.

Septal apparatus absent.

TYPE AND FIGURED SPECIMENS: Holotype T.1085-9; T.1090; T.1091; Loc. 48; M.3044, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 47 (occasional), 48 (common), 49 (occasional), Boola Beds.

REMARKS: This species resembles most closely the Lower and Middle Devonian *Coenites escharoides* (Steininger) from which, however, it differs in a number of respects. The corallum, in general, is slightly thinner, the corallites slightly smaller and open at an angle of 30° to the surface of the corallum, the mural pores are larger and the tabulae more irregularly developed. Moreover, the calices are very much wider in *C. planifolium*. As these differences are consistent, it is best to regard this form as a new species.

Coenites expansus de Koninck (*non* Frech) from the Middle Devonian of Murrumbidgee and Buchan differs from this species in possessing a much heavier corallum and larger corallites. Thus the mould illustrated by Etheridge (1899b) as *Coenites* sp. from the Lower Devonian of Sandy's Creek, Tabberabbera, resembles more closely *C. expansus* than *C. planifolium*.

C. planifolium is confined to the mudstone facies of the Boola Beds, where it occurs very often as moulds.

Subgenus *Cladopora* Hall 1851

DIAGNOSIS: *Coenites* in which the calices are round or ovate rather than alveoliteoid.

Coenites (Cladopora) foliata (Jones)

(Pl. XVII, fig. 5-6; Pl. XVIII, fig. 2)

Pachypora meridionalis Richards and Bryan 1924, Pl. 16, fig. 2.*Thamnopora foliata* Jones 1941, p. 48-9, Pl. 2, fig. 1-3.

DESCRIPTION: Corallum foliar or encrusting, up to 6 mm wide, irregular in thickness, averaging about 4 mm, with corallites opening on both surfaces of corallum. Occasionally massive or cylindrical, in which case made up of growth layers about 2.5 mm thick, and the corallites then arise from a thin layer of slightly thickened corallites at the base of each layer. Largest such corallum 15 mm thick. Corallites in this basal layer or usually median layer rounded ovate or subpolygonal averaging 0.25 mm in diameter with wall diameter 0.03 mm, with 2, 3 or 4 layers of corallites in this slightly thickened zone. Corallites usually bending sharply after leaving this zone to emerge usually normal to the surface of the corallum; calices circular to slightly ovate, usually about 0.2 mm in diameter, fairly constant in diameter in parts of a corallum, but occasionally reaching up to 0.3 mm. Thickness of wall between adjacent corallites up to 0.3 mm but averaging 0.25 mm.

Tabulae occasionally seen; thin, flat or slightly convex and normal to the growth direction of the corallites. Mural pores rarely encountered, about 0.07 mm in diameter. Tabulae and mural pores apparently confined to the median zone of the corallum.

Septal apparatus absent.

FIGURED SPECIMENS: T. 1095, T. 1100, Loc. 11; T. 1099, Loc. 19, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (occasional), 19 (rare), 20 (rare), 27 (common), Limestone Phase, Coopers Creek Formation.

REMARKS: Jones (1941), in describing this species from the Middle Devonian of Clermont, Queensland, commented on the difficulty of classifying this species at the generic level. Here it has been moved to the genus *Coenites* on the basis of the growth form of the corallum and the wall structure (i.e. the absence of any trace of the primary walls of the corallites in the dilated distal zone). It is included in that morphological section of the genus covered by the subgenus *Cladopora* on the basis of the rounded calices.

The Tyers material differs from Jones's description of this species in only one point and that is the size of the corallites at the surface of the corallum. These are larger in the Clermont form where the lumen is said to be about 0.35 mm in diameter. On the other hand the present material averages 0.2 mm in lumen diameter, although in places it may be as much as 0.3 mm.

Coenites (Cladopora) gippslandica (Chapman)

(Pl. XVIII, fig. 1, 3-7)

Rhombopora gippslandica Chapman 1907, p. 78, Pl. 2, fig. 4; Pl. 7, fig. 15.? *Acanthoclema flexuosa* Chapman 1920, p. 189, Pl. 24, fig. 20; Pl. 32, fig. 38-40; Gill 1949, p. 94.

DESCRIPTION: Corallum digitate, cylindrical to ovate in cross-section, between 2 mm and 8 mm in diameter, usually about 3 mm, with largest corallum collected 5 cm in length, but probably greatly in excess of this. Corallum often branched and flexed.

Corallum with axial zone of slightly thickened corallites averaging between 0.15 and 0.24 mm in different coralla, with 3 to 12 corallites in contact through this axial region. Walls in this zone as little as 0.02 mm in diameter, but up to 0.1 mm in some specimens in which case they are probably thickened by an irregular layer

of secondary calcite. Primary walls of corallites visible in axial region. Corallites leaving axial zone with abrupt change in direction of growth, then curving slightly away from the axial zone to emerge at an angle of about 40° to the surface of the corallum. Lumen diameter fairly constant throughout, with walls thickened gradually toward the surface of the corallum where they reach a thickness of about 0.3 mm between adjacent corallites, but may be as little as 0.1 mm. Calices rounded or slightly elongate and aligned in fairly regular vertical series.

Tabulae not observed. Mural pores only occasionally seen, apparently confined to the axial zone of the corallum where they occur toward the centre of the corallite faces, about 0.08 mm in diameter, irregularly spaced, although in certain coralla fairly constant where they average as close as 0.5 mm apart.

Septal apparatus absent.

FIGURED SPECIMENS: M.3014 — T.1109, 1110, Loc. 11, Limestone Phase, Coopers Creek Formation; T.1111-4, Loc. 48, Boola Beds.

OCCURRENCE: Loc. 1 (rare), 4 (rare), 11 (common), 15 (occasional), 16 (rare), 18 (rare), 19 (rare), 20 (occasional), 21 (rare), 22 (rare), 26 (rare), 27 (common), Limestone Phase, Coopers Creek Formation; Loc. 35 (rare), 36 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 40 (rare), 43 (rare), 47 (occasional), 48 (common), 49 (occasional), Boola Beds.

REMARKS: This species proved to be particularly variable in the size of the corallum. In specimens from the mudstone facies of the Boola Beds the coralla are generally thinner perhaps also with less distal thickening of the walls, whereas in the overlying limestone facies they tend to be larger and stronger. Even so, no satisfactory subdivision of the species could be achieved, as specimens identical with the mudstone form are present among specimens from the limestone. As the internal features of all the specimens examined are fairly constant, and as there is a continuous range of variation in the size of the corallum, it is best to regard the specimens as representatives of one variable species.

Coenites (*Cladopora*) *gippslandica* belongs to a group of species allied to *Cladopora seriata* Hall 1852, the Middle Silurian type species of the genus. This species group includes the North American Middle Devonian *Cladopora bifurcata* Grabau (1910, p. 115, Pl. 10, fig. 2-4; Pl. 12, fig. 7-8; Pl. 15, fig. 1), *Cladopora gracilis* (Saleé 1915, MS.) (Lecompte 1939, p. 78-80, Pl. 12, fig. 6-10; Stasinska 1958, p. 195-6, Pl. 7) from the Middle and Upper Devonian of Europe and *Coenites declivis* Weissner (1939, p. 70-2, Pl. 6, fig. 4-6) from the Coblenzian of Bosphorus. Of these *C. (Cladopora) gippslandica* is perhaps closest to *Coenites declivis* Weissner from which it differs in possessing a generally smaller corallum and larger corallites. Close comparison with many of the North American species of similar dimensions is difficult, as their internal structure is often undescribed.

Acanthoclema flexuosa Chapman 1920, based on moulds from the Silurian of the Wombat Cr. area in NE. Victoria, and recorded by Gill (1949) from the Lower Devonian of Sandy's Cr., Tabberabbera, is in all probability a synonym of *C. (Cladopora) gippslandica*, which is also recorded by Chapman (1907) from mudstone in the Wombat Cr. area.

Certain Australian species described in the genus *Thamnopora* (e.g. *Thamnopora meridionalis* var. *minor* Jones 1941 from the Middle Devonian of Clermont and *T. angulata* Hill 1950 from the Middle Devonian of Buchan) resemble *C. gippslandica* in the sizes of the corallum and the corallites, and could also be species of *Cladopora*.

Genus *Fossopora* Etheridge 1903*Fossopora quintaria* sp. nov.

(Pl. XX, fig. 1-2)

DIAGNOSIS: Corallum discoidal; corallites averaging 0.5 mm with thick, amalgamated walls averaging 0.2 mm thick, with 5 strong lamellar septa extending over half way to the axis. Tabulae thin, fairly regularly spaced, between 16 and 20 per cm, in places developed at similar heights in adjacent corallites. Mural pores ovate, averaging about 0.16 mm in diameter, uniserial or irregularly biserial, averaging 0.7 mm apart.

DESCRIPTION: Corallum discoidal (largest in collection fragmentary, 50 mm in diameter and averaging 10 mm thick) or laminated with growth layers about 7 mm thick with basal zone on undilated corallites parallel to base of corallum.

Corallites within the corallum parallel, averaging 0.5 mm in diameter, with thick walls, typically with 5 strong lamellar septa obscuring the shape of the lumen. Walls averaging 0.2 mm thick but highly variable, between 0.1 mm and 0.4 mm, amalgamate, without primary corallite walls.

Tabulae thin, straight, occasionally incomplete or inosculating, fairly regularly spaced between 16 and 20 per cm, in places developed at the same height in adjacent corallites. Mural pores ovate to circular, averaging 0.18 mm by 0.14 mm with largest dimension parallel to growth direction, apparent in transverse sections as tunnels through the thick walls and developed in an irregular series toward the centres of the corallite faces between the septa, up to 1 mm apart, but averaging about 0.7 mm, occasionally irregularly biserial alternate. Pore plates usually present.

Septa of long thick lamellar projections extending over halfway into the centre of the lumen, constant in width with rounded ends, only rarely acanthine along their free edges. 5 septa present in adult corallites but in smaller corallites 4 or even 3 poorly developed septa present.

TYPE AND FIGURED SPECIMEN: Holotype M.3015 — T.1124-5, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (occasional), 19 (rare), 21 (rare), 27 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: Lafuste (1958) showed that mural pores are absent in *Thecia swinderniana* (Goldf.) and so removed this genus and its synonym *Romngella* Amsden 1949 from the Favositidae. Thus there are left the following closely related favositid genera with lamellar septa, all of which are based on, in all likelihood, Silurian type species:

Laceripora Eichwald 1854, type species *L. cribose* Eich., from the Silurian (?) of Estonia.

Somphopora Lindström 1883, type species *S. daedalea* Lind., from the Silurian of China.

Fossopora Etheridge 1903, type species *F. wellingtonensis* Eth., from the Silurian (?) of N.S.W.

Boreaster Lambe 1906, type species *B. lowi* Lambe, from the Silurian of Arctic Canada.

Angopora Jones 1936 (*pro Laminopora* Jones 1930), type species *A. hisingeri* Jones, from the Silurian of Gotland.

Stable generic characters are extremely difficult to assess in this group, particularly as most of these genera have remained monotypic since their proposal.

There can be little doubt that at least *Fossopora* and *Boreaster* are synonymous, and that many of the species with mural pores originally described in the genus *Thecia* should be transferred to the genus *Angopora* Jones. The new species is placed in the genus *Fossopora* Eth. because of its general similarity to *F. wellingtonensis* although it differs from this species in that the septa only rarely become spinose along their free edges and the tabulae may be at the same height in adjacent corallites. Furthermore the septa are but 5 in number in adult corallites. It seems best at present to expand the genus *Fossopora* to include this species rather than propose a new genus for its reception.

Comparison can be drawn between *F. quintaria* and certain species described in the genus *Thecia* (e.g. *Thecia devonia* Charlesworth 1914, p. 381-2, Pl. 34, fig. 11, from the Lower Devonian of the Carnic Alps, and *Thecia minimorum* Barrande, Pořta 1902, p. 278, Pl. 93, 114, from the Koněprus), but from these and related species *F. quintaria* differs in the possession of 5 septa.

The fine structure of the skeleton of *F. quintaria* is virtually identical with that of *Thecia swinderniana* (Goldf.) described by Lafuste (1958) as being trabecular. The walls consist of well developed calcite fibres directed upwards and outwards from the median plane which consists of a zone of usually clearer calcite. The fine structure of the septa is similar, with fibres again radiating from a median zone. The walls are amalgamated, with no trace of primary corallite walls, and carbonaceous matter is often incorporated in them. The structure of the septa is thus comparable with the monacanthine septa of rugose and scleractinian corals, in as much as each septum can be regarded as consisting of a single, flattened trabecula. No marked distinction can be drawn between this type of wall structure and that of *Favosites* as has been suggested by Lafuste (1958). In *Favosites* one finds that the slightly felted fibres of the peripheral stereozone are again radiating upwards, although usually this is not so apparent as in *F. quintaria*. In the case of *Favosites* the fibres radiate from the thin, primary walls of the corallites. As the septal apparatus, both squamulae and septal spines, is trabeculate in favositids (Kraicz 1937; Hill 1950; Hill and Stumm 1956) the only real distinction which can be drawn is in the absence of primary walls in *Thecia swinderniana* and *F. quintaria*. However in certain genera of the Favositidae (e.g. *Coenites*) the primary walls of the corallites may be visible in unthickened portions of a corallum, where the walls are slightly thickened, but are absent in the distally dilated walls.

Genus *Pleurodictyum* Goldfuss 1829

Pleurodictyum megastoma McCoy

(Pl. XXI, fig. 1, 6)

Pleurodictynis megastoma McCoy 1866, p. 34.

Pleurodictyum megastoma McCoy 1867, p. 23.

Pleurodictyum megastoma McCoy 1867b, p. 201.

Pleurodictyum megastomum McCoy, Etheridge 1878, p. 13.

Pleurodictyum ? *problematicum* Goldf., Foerste 1888, p. 132-5, Pl. 13, fig. 22.

Pleurodictyum sp. (? *P. megastomum* McCoy MS.) Dun 1898, p. 83-5, Pl. 3, fig. 1.

Pleurodictyum megastomum Dun, Chapman 1903a, p. 105, Pl. 16, fig. 2-5; Chapman 1908, p. 222; Chapman 1914b, p. 111, Fig. 69e; Chapman 1921, p. 216, Pl. 9, fig. 4-6; Allan 1929, p. 322; Withers 1932, p. 15-19, Fig. 1-6; Shirley 1938, p. 463-4, Pl. 60, fig. 5-8; Gill 1942, p. 35-6, Pl. 4, fig. 1, 3, 4, 6, 9.

Pleurodictyum megastomum McCoy, Hill 1942b, p. 8, Pl. 2, fig. 5.

Pleurodictyum megastomum Dun, Gill 1948, p. 66, Pl. 8, fig. 13; Gill 1950, p. 241.

Pleurodictyum megastomum McCoy, Bassler 1950, p. 128.

DESCRIPTION: (Based on moulds.) Corallum flat, discoidal, up to 2 cm in diameter with well developed basal epitheca showing irregular concentric growth lamellae.

Corallites with calices up to 4 mm in depth and up to 7 mm in diameter, usually averaging 5 mm, fairly constant within the one corallum with up to 9 corallites in the one corallum. Walls of the order of 0.5 mm or thicker.

Apparently few tabulae present, surfaces covered by short, upwardly directed spines which continue without interruption on to the corallite walls to form the septal spines of the calices where they may become aligned on very low septal ridges about 0.8 mm apart. Spines usually stronger on the surface of the tabulae. Mural pores less than 0.2 mm in diameter, randomly disposed on the corallite faces, about 0.5 mm apart, often obscuring the low septal ridges.

FIGURED SPECIMENS: M.3013, Loc. 36, Conglomerate Phase, Coopers Creek Formation; M.3012, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 35 (rare), 36 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 43 (rare), 47 (occasional), 49 (occasional), Boola Beds.

REMARKS: The original description of McCoy (published three times), although merely referring to the size of the corallites, is sufficient to characterize this species. As the first two spellings of the specific clearly represent *lapsi calami* the trivial name should be rendered *megastoma*, as Etheridge's (1878) emendation of the spelling is invalid.

From the synonymy it can be seen that *P. megastoma* has been recorded and described more often than any other Victorian Silurian and Devonian species. Because of its widespread occurrence, an attempt was made to subdivide this species on the basis of the size of corallites. However, the material available was found insufficient to characterize adequately the variation between different specimens from the one horizon. All that can be said at this stage is that there appears to be a certain increase in size and variability of the corallite diameter in specimens from younger horizons in the Yeringian. Thus specimens from Kinglake may show an average corallite diameter of up to 14 mm, whereas the specimens illustrated by Gill (1948, 1950) from Tasmania have an average corallite diameter of less than 5 mm.

Although the material from Tyers has only specimens with 3 to 9 corallites present in a corallum, as many as 28 have been recorded in *P. megastoma* (Gill 1942).

Among overseas species *P. megastoma* is perhaps most closely allied to the Coblenzian *P. constantinopolitanum* Roemer (1863, p. 519, Pl. 5, fig. 1) from Bosphorus which Weissermel (1939) has considered to be possibly synonymous with *P. giganteum* Kayser (1889, p. 295) from the Lower Devonian of the Rheinischer Schiefergebirge. Shirley (1938) also points to the similarity between *P. megastoma* and *P. petrii* Maurer and the closely related *P. hunsrückianum* Fuchs. *Pleurodictyum nodai* Yabe and Sugiyama 1942 (p. 499-500, Fig. 1a-b) is a Japanese species also difficult to distinguish from *P. megastoma*.

P. megastoma is at present taken as sure indication of the Devonian age of the rocks in which it occurs. Certainly the genus is restricted to the Devonian of Europe where it first appears in the Upper Gedinian (Asselberghs 1946). However in North America, Amsden (1949) has described *P. tennesseensis* from the Brownsport Formation of Niagaran age. This species is not unlike the smaller celled varieties of *P. megastoma*.

Family HELIOLITIDAE Lindström

Genus *Heliolites* Dana 1846*Heliolites daintreei* Nicholson and Etheridge

(Pl. XVII, fig. 7; Pl. XIX, fig. 1-4)

Heliolites Daintreei Nicholson and Etheridge 1879, p. 224, Pl. 14, fig. 3-3a.*Heliolites barrandei* Pen. var. *turcica* Weissermel 1939, p. 88-91, Pl. 9, fig. 4; Pl. 10, fig. 1-3.*Heliolites daintreei* Nicholson and Etheridge, Jones and Hill 1940, p. 199-203, Pl. 6, fig. 1-5;Pl. 7, fig. 1-5; Pl. 8, fig. 1-8; Pl. 9, fig. 1 (*cum syn.*); Jones 1944, p. 37-8, Pl. 1, fig. 9-10.*Heliolites regularis* Dun var. *kuznetskiensis* Chernyshev 1951, p. 89-90, Pl. 22, fig. 6-7.*Heliolites tomensis* Chernyshev 1951, p. 90-1, Pl. 23, fig. 1-2.*Heliolites insolens* Chernyshev 1951, p. 91-2, Pl. 23, fig. 3.*Heliolites daintreei* Nicholson and Etheridge, Hill 1954b, p. 115, Pl. 9, fig. 30.*Heliolites Barrandei* Penecke, Fontaine 1954, p. 68-70, Pl. 8, fig. 5-9.

DIAGNOSIS: (After Jones and Hill 1940.) Corallum sub-hemispherical, tabularia between 0.5 and 2 mm in diameter, consistent within the one corallum, up to 6 mm apart, separated by sub-polygonal coenenchymal tubes about 0.3 mm in diameter. Tabularia with 12 variably developed lamellar septa forming upwardly developed spines which may extend into the centres of the tabularia.

DESCRIPTION OF TYERS MATERIAL: Corallum hemispherical, largest in collection 13 cm in diameter.

Tabularia parallel or slightly expanding, rounded or with slightly crenulate walls, averaging between 0.8 and 1.7 mm in diameter in different coralla, consistent within the one corallum, regularly spaced, averaging between 0.3 and 0.8 mm apart, separated by coenenchymal tubes averaging between 0.25 and 0.35 mm in diameter, usually 6-sided with rounded corners. Walls averaging 0.04 mm, thickened to 0.1 mm around the tabularia. Occasionally walls of coenenchymal tubes thickened also.

Tabulae within the tabularia thin, usually horizontal, occasionally inclined, incomplete or inosculating, between 15 and 34 per cm. Sola within the coenenchymal tubes 19 to 40 per cm.

Septa within the tabularia variably developed, 12 in number, laminar, giving rise to strong, upwardly curved, septal spines along the free edge. In certain sections however septa virtually absent. Where walls crenulate, septa developed on the angles which protrude into tabularium.

FIGURED SPECIMENS: T.1131, Loc. 11; T.1133-4, Loc. 20; T.1135-6, Loc. 19, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 7 (rare), 11 (common), 15 (rare), 19 (rare), 20 (rare), 22 (rare), 27 (occasional), Limestone Phase; Loc. 33 (occasional), Conglomerate Phase, Coopers Creek Formation; Loc. 48 (rare), 49 (rare), Boola Beds.

REMARKS: Jones and Hill (1940), in a revision of the Heliolitidae of Australia, interpreted the widespread Silurian and Devonian *H. daintreei* as a particularly variable species, and, from the extensive collections at their disposal, were merely able to recognize four ill-defined groups within the species. They concluded that *H. barrandei* Pen., as interpreted by Lindström (1899) is conspecific with *H. daintreei* and regarded four of Dun's (1927) species from Yass, as well as two of Kettnerova's (1933a, b) species from the Koněprus as synonyms or possible synonyms of *H. daintreei*. Chernyshev (1951), in describing the Silurian and Devonian Heliolitidae from the Kuznetsk Basin, has added at least three more names to the synonymy of this species. Furthermore his *Heliolites vulgaris* and its two

varieties are further possible synonyms of *H. daintreei* although Chernyshev states in each case that septa are absent.

The specimens from Tyers fall within the range of variation of Jones and Hill's 'Group IV'. The specimens from the mudstone facies of the Boola Beds show smaller tabularia and more strongly developed septal apparatus than those from the limestone.

Genus *Plasmopora* Edwards and Haime 1849

Plasmopora gippslandica (Chapman)

(Pl. XIX, fig. 5-6)

Heliolites interstincta var. *gippslandica* Chapman 1914, p. 311, Pl. 9, fig. 35-6.

Plasmopora gippslandica (Chapman) Jones and Hill 1940, p. 206, 208, Pl. 10, fig. 5; Pl. 11, fig. 1.

Heliolites yavorskyi Chernyshev 1951, p. 98-9, Pl. 25, fig. 1-3.

Heliolites kvosčeviensis Zhmeav, in Halfina 1955, p. 205-6, Pl. 33, fig. 4a-b.

DESCRIPTION: Corallum hemispherical, largest in collection 5 cm in diameter.

Tabularia parallel or slightly radiating, averaging between 0.8 and 1 mm in diameter in different coralla, regularly spaced, averaging 0.5 mm apart, with usually 2 coenenchymal tubules between each tabularium, but from 1 to 4. Coenenchymal tubules polyhedral, averaging about 0.25 mm in diameter with continuous vertical walls, those of the aureole of 12 surrounding the tabularia not well differentiated, occasionally somewhat larger and more elongate radial to the tabularia. Walls averaging 0.04 mm in diameter increasing to 0.08 mm around the tabularium.

Tabulae within the tabularia, thin, flat, occasionally incomplete or inosculating, averaging about 34 per cm. Sola within coenenchymal tubes averaging 45 per cm.

No septal apparatus.

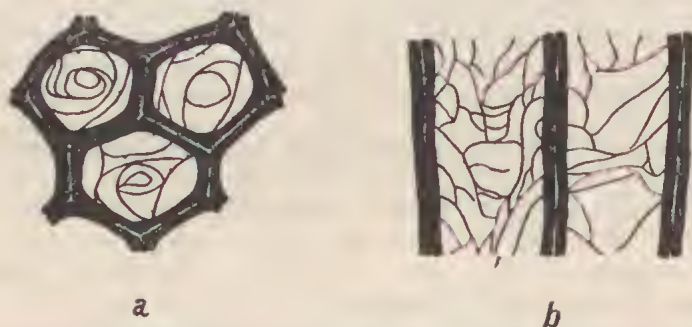


FIG. 3—*Roemeria thomii* (Chapman). (a) T.S., (b) L.S. Composite drawings showing the nature of the tabulae, based on portions of T. 1161-2 and M. 3013. x 4 approx.

FIGURED SPECIMEN: T.1056-7, from M.3017, Loc. 5, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 5 (rare), 11 (rare), Limestone Phase, Coopers Creek Formation; Loc. 43 (rare), 48 (rare), Boola Beds.

REMARKS: Hill and Jones (1940) give the diameter of the tabularia in this species as between 1 and 1.5 mm whereas the Tyers material shows an average tabularium diameter between 0.8 and 1 mm. There can be little doubt that the Tyers form is conspecific with *P. gippslandica* particularly as Chapman's original material came from the same horizon at Coopers Creek, just to the north.

Chernyshev's (1951) *Heliolites yavorskyi* from the Upper Silurian of the Kuznetsk Basin is undoubtedly conspecific with *P. gippslandica*; the only slight difference is that the tabularia are said to be between 0.7 and 0.8 mm in diameter in that species. *Heliolites kvosčeviensis* Zhmeav is a further Russian species of *Plasmopora* indistinguishable from *P. gippslandica*, while again *Plasmopora aseptata* Regnéll (1941, p. 50-2, Pl. 12, fig. 2-5), from the Siluro-Devonian of Tien-Shan, represents another identical or closely related species. The only apparent distinction between it and *P. gippslandica* lies in the coenenchymal tubules which are more often shared between neighbouring tabularia in Regnéll's species. Jones and Hill have already pointed to the close comparison which exists between *P. gippslandica* and the Middle Devonian *P. carnica* Vinassa de Regny 1918.

Family AULOPORIDAE Edwards and Haime

Genus *Roemeria* Edwards and Haime 1851

Roemeria thomii (Chapman)

(Pl. XX, fig. 3-4; Fig. 3)

Syringopora thomii Chapman 1921, p. 222-3, Pl. 10, fig. 14-16.

DESCRIPTION: Corallum hemispherical, up to 5 cm in diameter, partly cerioid. Corallites polygonal, 6-sided or in places cylindrical where the corallites are loosely united. Corallite diameter averaging 4.5 mm with common walls 0.6 mm in diameter.

Tabulae thin, crowded, long and steeply inclined, forming an irregular axial tube. Mural pores irregularly developed, about 0.5 mm in diameter. Small septal spines occasionally visible around the periphery of the lumen.

FIGURED SPECIMEN: T.1161-2 from M.3013, Loc. 22, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 21 (rare), 22 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The two specimens in the collection are so poorly preserved that very little can be added to the brief description of this species given by Chapman (1921).

R. thomii is intermediate in corallite diameter between *R. progenitor* (Chapman 1921) from the Lilydale Limestone and *R. ocellata* Hill 1950 from the Middle Devonian of Buchan. It further differs from those species in possessing only poorly developed spines on the upper surfaces of the tabulae.

Genus *Aulopora* Goldfuss 1829

Aulopora sp. affin. *A. emergens* Quenstedt

(Pl. XX, fig. 5-6)

Affin. *Aulopora emergens* Quenstedt 1881, p. 103-4, Pl. 147.

Affin. *Aulopora emergens* Quenstedt, Kettner 1934, p. 7-11, Fig. 6-7.

DESCRIPTION: Corallum of loosely compacted tubes, often in contact, forming large masses up to 15 cm in diameter. Corallites cylindrical, up to 0.9 mm in diameter, averaging between 0.7 and 0.8 mm in different slides, as many as 6 in contact at the one height, flattened along the surfaces of contact. Peripheral stereozone variable, up to 0.3 mm in diameter and as little as 0.1 mm, averaging about 0.2 mm.

Tabulae thin, irregular, in places horizontal or convex, sometimes steeply inclined and even simulating dissepiments, rarely infundibuliform, usually incomplete. Con-

necting processes between corallites absent but occasional breaks in walls present where the corallites are in contact.

Septal spines absent or extremely rudimentary.

FIGURED SPECIMEN: T.1166-7, Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (occasional), 15 (rare), 22 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation.

Moulds from Loc. 47, Boola Beds, with similar corallite diameter, are doubtfully included in this species.

REMARKS: The specimens from the limestone agree closely with the description of the species given by Kettner (1934), although the figures given suggest a form of slightly larger corallite diameter than the material from Tyers. Kettner's specimens, from the Devonian of Bohemia, possess similarly distributed tabulae and also occasional breaks in the corallite walls connecting the corallites where they are in contact. There can be little doubt that the Tyers material is very closely allied to Quenstedt's species, as interpreted by Kettner, although the thin sections of this form, taken from massive limestone, do not define adequately either its calices or mode of increase. *A. cf. conglomerata* Goldfuss of Hill (1950) from the Middle Devonian of Buchan is a species with similar corallite diameter.

Order RUGOSA

Suborder STREPTELASMATINA

Family LACCOPHYLLIDAE Grabau

DIAGNOSIS: Comparatively small, solitary rugose corals with axial ends of major septa united at an aulos which divides a series of horizontal inner tabellae from an outer series of inclined tabellae; minor septa, when present, contratingent; dissepiments occasionally developed in the interseptal loculi, or rarely lonsdaleoid.

REMARKS: Hill (1939), Stumm (1949b) and Hill (1956a) state in diagnosis of the family Laccophyllidae (= Syringaxonidae) that members of this family do not possess dissepiments. However, dissepiments have been described in species assigned to genera of this family. For example, Hill (1950) described as *Syringaxon radiatum* a species from the Middle Devonian of Buchan in which (p. 144) 'occasionally in the distal parts of the corallite a few dissepiments may be developed between one minor septum and its neighbouring major septum': Hill (1954a) has further described species of *Barrandeophyllum* which possess occasional dissepiments either between major and minor septa, or rarely lonsdaleoid dissepiments, causing discontinuity in the septa. *Catactotoechus* Hill 1954, a laccophyllid genus in which the minor septa are absent, possesses a single incomplete series of dissepiments, each connecting two major septa. Prantl (1938), followed by Schouppé (1951b, 1954a), have considered that dissepiments are present in *Barrandeophyllum perplexum* Počta, the type species of the genus *Barrandeophyllum* Počta 1902. Thus Schouppé (1951, 1954a) regarded the difference between *Syringaxon* and *Barrandeophyllum* to be that, in the latter genus, dissepiments can be seen in transverse sections between the septa forming interseptal 'Querverbindungen'. Rather than dissepiments these appear to be supplementary tabulae. In *Syringaxon* (*Saucrophyllum*) *pocillum* subgenus et sp. nov. dissepiments are consistently developed in a single vertical series in the interseptal loculi between the major and minor septa. Thus the family diagnosis given above has been modified to include forms with dissepiments.

Genus *Syringaxon* Lindström 1882

Following Schouppé (1951b, 1954a), *Barrandeophyllum* Pošta 1902 is regarded as a subgenus of *Syringaxon*. The thickening of the septa and of the well formed aulos in species of *Syringaxon* do not appear to be characters of sufficient merit to justify the generic separation. Although usually present, minor septa may be absent in either subgenus. A further subgenus *Saucrophyllum* nov. is proposed in which a vertical series of dissepiments occurs between the major and minor septa. Wang (1950) has recognized *Duncanella* Nicholson 1874 as another subgenus of *Syringaxon* to include species in which the septa are entirely lamellar rather than medially trabeculate.

Subgenus *Syringaxon* Lindström*Syringaxon* (*Syringaxon*) sp.

(Pl. XXII, fig. 9)

DESCRIPTION: Small, solitary, trochoid corals, round or ovate in transverse section, up to 6 mm in diameter and with height up to 1 cm; calyx about 5 mm deep in adult specimens. Epitheca with only faint growth striations.

Major septa about 20 in adult specimens with contratingent minor septa extending up to half way to the aulos and resting on all but the cardinal, counter and counter-lateral septa. Septa with only a very thin medial trabeculate zone, strongly thickened by lamellar stereone, often to the exclusion of the interseptal loculi between the contratingent septa which are uniform in thickness throughout their length. Aulos well developed, small, circular to strongly ovate in transverse section, with internal diameter between 0.5 and 1.2 mm, formed by the fitting together of the axial ends of the dilated major septa with the sutures between the septa usually visible.

Peripheral stereozone thin, about 0.2 mm in diameter. Tabulae few, those within the aulos horizontal. Dissepiments absent.

FIGURED SPECIMEN: T.1176, Loc. 50, Boola Beds.

OCCURRENCE: Loc. 40 (occasional), 43 (rare), 47 (occasional), 48 (occasional), 50 (occasional), Boola Beds.

REMARKS: The extreme thickening of the septa in this species, which is confined to the mudstone facies of the Boola Beds, serves to distinguish it from other North American and European species of *Syringaxon*. In this dilation of the septa it contrasts with the laccophyllids of the limestone facies of the Coopers Creek Formation. It is of interest to note that Prantl (1938) has mentioned that the amount of thickening within the Devonian species of *Syringaxon* from Bohemia is greater in species from shales than it is in species from limestone.

In size and number of septa the species is most closely allied to the Silurian *Syringaxon siluriensis* (McCoy) from which it differs in other respects apart from the dilation of the septa (e.g. the absence of counter-lateral minor septa). The ontogeny of the two species is apparently very different, for at a diameter of 1.4 mm our present species possesses a well formed aulos and 12 septa, whereas in *Syringaxon siluriensis* a poorly formed aulos first appears at a diameter of about 4 mm where most of the major septa have developed and the minor septa have appeared (*vide* Butler 1935).

The material to hand from the massive mudstones of the Boola Beds did not produce one longitudinal section which adequately defined the nature of the tabulae in this species. For this reason the species has not been named.

Moulds of species of *Syringaxon* are not uncommon in the Siluro-Devonian sequences of Lilydale and Kinglake, but positive identification of these is virtually impossible in the absence of hard parts.

Subgenus *Barrandeophyllum* Pořta 1902

Syringaxon (*Barrandeophyllum*) sp.

(Pl. XXII, fig. 10)

DESCRIPTION: Small, solitary, trochoid corals up to 8 mm in diameter.

Major septa 18 in number at diameter of 4 mm increasing to 21 at a diameter of 8 mm. Minor septa absent. Aulos with internal diameter of about 1 mm or usually less, often poorly defined or with irregular thickening; cardinal septum may extend further into aulos than other septa. Septa moderately thick, fairly constant in diameter, averaging about 0.2 mm.

Peripheral stereozone up to 2 mm across. Tabulae abundant and inclined in outer series, apparently horizontal within the aulos.

FIGURED SPECIMEN: T. 1184, Loc. 15, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (rare), 15 (occasional), 20 (occasional), Limestone Phase; Loc. 28 (rare), Conglomerate Phase, Coopers Creek Formation.

REMARKS: Because of the variable development of the aulos and the slightly thickened septa, this species is placed in the subgenus *Barrandeophyllum*. Again the material available does not adequately define this species. It could be that more than one species is represented among the 6 specimens here regarded as conspecific.

Syringaxon inopinata Prantl (1938, p. 312, Pl. 1, fig. 6; Fig. 3) from the Middle Devonian of Bohemia and *Barrandeophyllum rubrum* Hill (1939c, p. 142-3, Pl. 1, fig. 1, 2) from the Devonian of Western Australia are other species of *Syringaxon* which lack minor septa.

Subgenus *Saucrophyllum* subgenus nov.

DIAGNOSIS: Comparatively large *Syringaxon* with a single row of inclined dissepiments consistently developed between the contratingent major and minor septa.

TYPE SPECIES: *Syringaxon* (*Saucrophyllum*) *pocillum* sp. nov.

REMARKS: It seems a worthwhile procedure to recognize a category within *Syringaxon* to include species in which dissepiments are present within the interseptal loculi. Schouppé (1951b, 1954a) has ascribed this feature to the subgenus *Barrandeophyllum* but it appears that in species of *Barrandeophyllum* the partitions between the interseptal loculi are accessory tabulae. These may also be seen in *Syringaxon siluriensis* (McCoy) in transverse sections above the aulos (Butler 1935, Pl. 2, fig. 7).

Syringaxon (*Saucrophyllum*) *pocillum* sp. nov.

(Pl. XXII, fig. 1-8)

DESCRIPTION: Moderately large, solitary, trochoid corals up to 18 mm in diameter and 25 mm in height. Calyx about 1 cm deep in adult specimens. Epitheca with strong vertical interseptal costae.

Major septa up to 31 in adult specimens with contratingent minor septa often extending over half-way to the aulos, usually present resting against all but the

cardinal, counter and counter-lateral septa. Occasionally minor septa not resting against major septa. Major septa, with the exception of the counter-laterals, thicker than minor septa, and somewhat attenuated half-way to the aulos. They are dilated at their extremity to give rise to a well formed aulos up to 5 mm in internal diameter with the axial ends of the septa projecting slightly into the aulos, particularly the cardinal and counter septa. Peripheral stereozone about 0.5 mm thick.

Tabulae within the aulos horizontal, sometimes incomplete, 4 to 7 per 5 mm, usually closer than the outer series between the major septa. A single row of moderately large inclined dissepiments developed within each interseptal loculus between the contratingent septa, extending the full height of the minor septa, well above the calyx.

TYPE AND FIGURED SPECIMENS: Holotype M. 3021—longitudinal and tangential sections T. 1190-1; Paratype reduced to 7 serially cut transverse sections T. 1192-8; both from Loc. 50, Boola Beds.

OCCURRENCE: Loc. 6 (rare), 11 (rare), 19 (rare), Limestone Phase; Loc. 33 (rare), 35 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 40 (occasional), 48 (rare), 50 (common), Boola Beds.

REMARKS: In transverse section the septa in this species consist of a thin median zone of very dense calcite fibres expanding considerably near the aulos. Investing this median layer is a zone of lamellar stereome which thickens toward the walls and the aulos. In longitudinal section the median zone of the septa may be seen to consist of closely superposed trabeculae which are approximately horizontal or with a slight upward inclination toward the aulos. This fine structure is similar to that of *Syringaxon siluriensis* (McCoy) as described by Wang (1950).

The specimens from Coopers Creek Formation show less thickening of the septa than those from the mudstone of the Boola Beds. Moreover, they are usually smaller and possess fewer septa. They are included, however, in *Syringaxon* (*Saucrophylum*) *pocillum* for the present.

Syringaxon radiatum Hill (1950, p. 144, Pl. 6, fig. 14-15), from the Middle Devonian of Buchan, is possibly a related species although dissepiments are only developed in the proximal parts of the corallum.

Family MYCOPHYLLIDAE Hill

Genus *Pseudamplexus* Weissermel 1879

Pseudamplexus princeps (Etheridge)

(Pl. XXII, fig. 13)

Tryplasma princeps Etheridge 1907, p. 97, Pl. 15, fig. 1; Pl. 17, fig. 1-5 (*non* 6); Pl. 18, fig. 1, 7; Pl. 19, fig. 1-3; Pl. 20; Pl. 21, fig. 1-9; Pl. 22, fig. 1, 10; Pl. 23, fig. 1-3.

Pseudamplexus aff. *princeps* (Etheridge) Hill 1940a, p. 267.

Pseudamplexus princeps Etheridge, Hill and Jones 1941, p. 185-6, Pl. 3, fig. 1-2.

Pseudamplexus princeps (Etheridge) Hill 1942c, p. 159; Hill 1942e, p. 19.

Pseudamplexus ? *princeps* (Etheridge) Hill 1950, p. 142.

DESCRIPTION: Large, conical corals up to 35 mm in diameter.

Septa about 70 in number, major and minor septa equally developed, about 2 to 3.5 mm long, dilated at their base so as to be in contact and so giving rise to a peripheral stereozone between 1 and 2.5 mm wide.

Tabulae flat, horizontal, often incomplete, averaging about 1 mm apart. Dissepiments absent.

FIGURED SPECIMEN: T.1508 from M.3023, Loc. 19, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 19 (rare), Limestone Phase; Loc. 33 (rare), Conglomerate Phase, Coopers Creek Formation. One specimen from Loc. 11, showing differentiation of the major and minor septa and a thicker peripheral stereozone, is questionably placed in this species.

REMARKS: In a massive limestone which consists of largely reworked organic debris, it is virtually impossible to establish whether or not this form is sub-compound as is typical of *Pseudamplexus princeps* (Etheridge). In its internal characteristics it agrees with Etheridge's species. The micro-structure of this species has been discussed by Hill (1940a) and Hill and Jones (1941).

Pseudamplexus princeps var. *confertus* var. nov.

(Pl. XXI, fig. 3; Pl. XXII, fig. 11-12)

DIAGNOSIS: *Pseudamplexus princeps* with trochoid coralla and wide peripheral stereozone about 8 mm in diameter.

DESCRIPTION: Corallum large, trochoid, expanding uniformly to a diameter of up to 12 cm over a height of about 16 cm. Calyx about 10 cm deep. Surface apparently marked by longitudinal ridges.

Septa about 85 in number at a diameter of 9 cm, with major and minor septa equally developed, up to 12 mm long and averaging about 10 mm with the last 2 mm free, the rest dilated to form a wide peripheral zone around the corallum. Septa apparently acanthine, occasionally encountered as discrete spines in transverse sections.

Tabulae flat, often incomplete, somewhat thickened, irregularly spaced, averaging about 8 per cm.

TYPE AND FIGURED SPECIMEN: Holotype M.3024 — T.1513-4, Loc. 19, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 19 (rare), 22 (rare), 23 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: This form is closely allied to typical *P. princeps* from which it may be distinguished primarily on the basis of the longer septa and the thicker peripheral zone of dilated septa. In this feature it approaches more closely the European Lower Devonian species (e.g. *P. bohemicus* (Barrande), Počta 1902, Pl. 29-33; *P. ligeriensis* (Barrios), Charlesworth 1914, p. 352, Pl. 1a-b, 4-5). The corallum is also apparently more trochoid than is typical of *P. princeps*.

Pseudamplexus sp. (= *Tryplasma princeps* Etheridge of Richards and Bryan 1924) of Hill (1940a) from the Silverwood-Lucky Valley area of Queensland could belong to this new variety, as the dilation and length of the septa are similar. However, the septa are very thick, almost twice that typical of the new variety.

The micro-structure of this form is very similar to *P. princeps*, consisting of large rhabdacanthine trabeculae embedded in lamellar tissue, which may project, however, as short acanthine septa.

Again, it is impossible to tell whether or not this form is sub-compound or solitary. From the material available it cannot be positively stated whether or not this form represents merely a population variant of *P. princeps* or is a separate species of *Pseudamplexus*. Certainly the differences between it and *P. princeps* are most striking.

Family ZAPHRENTIDAE Edwards and Haime

Genus *Heliophyllum* Hall 1846*Heliophyllum* sp. affin. *H. pinguiseptatum* Hill

(Pl. XXIII, fig. 1, 5)

Affin. *Heliophyllum pinguiseptatum* Hill 1954b, p. 110-I, Pl. 7, fig. 12a-c.

DESCRIPTION: Large, solitary, sub-trochoid coral, with diameter reaching 5 cm.

At a diameter of 4 cm approximately 48 major and minor septa present. Minor septa short, confined to a narrow dissepimentarium usually less than 6 mm wide, while major septa extend three-quarters of the way to the axis of the corallum. Septa of both orders strongly dilated within the dissepimentarium and bearing large, bulbous, yard-arm carinae which in longitudinal section appear as trabeculate flange plates curved upwards and inwards to the axis of the corallum. Dilation of major septa and degree of development of flange plates decreasing within the tabularium where the septa may become attenuated between the flange plates, but are again thickened at their axial ends. An irregular zone a few mm wide occurs around the periphery of the corallum where the septa and flange plates are unthickened. Epithecium thin and peripheral stereozone absent.

Dissepimentarium narrow, usually less than 6 mm wide, but extending up to 10 mm wide within the calcicular region. Dissepiments small, inclined, occasionally slightly thickened, difficult to distinguish in the flange plates, arrayed in about twenty irregular series.

Tabularium wide, consisting of a narrow, outer, upwardly inclined series simulating dissepiments and a wide, flat, close axial series, which may be slightly thickened. Calcicular floor thus domed, axially flat and marginally sloping toward the dissepimentarium; fossula not apparent.

FIGURED SPECIMEN AND OCCURRENCE: M.3025 — T.1517-8, Loc. 20, Limestone Phase, Coopers Creek Formation (rare).

REMARKS: This single specimen from the limestone, although similar in size and number of septa to *Heliophyllum pinguiseptatum* Hill from the Lower (?) Devonian of Waratah Bay, differs in a number of features. The most striking of these is in the major septa which in the specimen described by Hill are much more strongly dilated in the tabularium and extend to the axis of the corallum. Moreover, a cardinal fossula is also present. As but a single specimen of *H. pinguiseptatum* is known, the best procedure for the present is to equate the specimen from Tyers with Hill's species, while recognizing the differences which exist between the two. *H. pinguiseptatum* represented the first Australian occurrence of the North American and Moroccan genus *Heliophyllum*.

Family PHILLIPSASTRAEIDAE Roemer

Genus *Phillipsastrea* d'Orbigny 1849*Phillipsastrea maculosa* Hill

(Pl. XXII, fig. 14)

Phillipsastrea speciosa Chapman Hill 1939b (*partim*), Pl. 16, fig. 3-4 (*non* 1-2).*Phillipsastrea maculosa* Hill 1942c, p. 153, Pl. 3, fig. 5a-b; 1954b, p. 107, Pl. 6, fig. 1a-b.

DESCRIPTION: Corallum astreoid or thamnasterioid with axes of corallites between 10 and 13 mm apart, and with the tabularia up to 4 mm in diameter but usually about 2.5 mm. Up to 20 septa of each order with the major septa only slightly

longer than the minor septa which do not extend into the tabularia. Septa dilated in a zone around the tabularia 1·5 to 2 mm wide, but extending to neighbouring corallites as thin, irregularly carinate plates. Tabulae horizontal; dissepiments arched in zone of dilated septa.

FIGURED SPECIMEN: T.1519 from M.3026, Loc. 20, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (rare), 20 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The material, although fragmentary, undoubtedly belongs to this species.

Phillipsastrea speciosa Chapman

(Pl. XXIV, fig. 6)

Phillipsastraea speciosa Chapman 1914, p. 306, Pl. 49, fig. 10-11; Pl. 50, fig. 12-14.

Phillipsastraea speciosa Chapman, Hill 1939b (*partim*), p. 237-8, Pl. 16, fig. 1-2 (*non* 3-4); 1942d, Pl. 6, fig. 8a-b.

DESCRIPTION: Corallum astreoid with axes of corallites 5 mm apart and with tabularia 1·5 to 2 mm in diameter. 28 septa, with major septa more thickened and extending slightly further into the tabularium, dilated in a zone 1·5 to 2 mm wide around the tabularia where they may be slightly carinate.

FIGURED SPECIMEN AND OCCURRENCE: T. 1520, Loc. 15, Limestone Phase, Coopers Creek Formation (rare).

REMARKS: This species differs from *P. maculosa* Hill in the smaller and closer tabularia and in possessing fewer septa.



TA 1525

a



TA 1534

b

FIG. 4—*Hexagonaria appraximans* (Chapman) and *Disphyllum cognatum* sp. nov.
(a) T.S. of *Hexagonaria appraximans* (Chapman) from portion of T.1525;
(b) *Disphyllum cognatum* T.S., T.1538, section from holotype M.3030. x 3.

Genus *Hexagonaria* Gürich 1896*Hexagonaria approximans* (Chapman)

(Pl. XXIV, fig. 4, 8-9; Fig. 4a)

Cyathophyllum approximans Chapman 1914a, p. 304-5, Pl. 47, fig. 5-6.*Prismatophyllum approximans* (Chapman) Hill 1939b, p. 234.*Hexagonaria* aff. *approximans* (Chapman) Hill 1954b, p. 108, Pl. 6, fig. 4a-b.

DESCRIPTION: Corallum forming large discoidal cerioid masses, with corallites up to 3 cm in diameter, but usually between 10 and 15 mm.

Between 16 and 21 septa of each order present, with major septa usually extending to the axes of the corallites or slightly withdrawn, with the minor septa confined to the dissepimentarium. Major and minor septa slightly dilated within the dissepimentarium with the major septa attenuated in the tabularium; septa carinate, with degree of development varying from specimen to specimen. In general the septa bear yard-arm or more typically zig-zag carinae which are increasingly more strongly developed toward the periphery of the corallites, where, in large corallites, the septa may become attenuated and replaced by naotic dissepiments. Common wall between corallites about 0.1 to 0.2 mm thick.

Dissepimentarium comparatively wide, consisting of up to 11 series of fairly small, thin, globose dissepiments which become progressively more inclined axially. Tabularium narrow, averaging 3.5 mm in diameter, with tabular floors domed to give an irregular axial boss, with flat, well spaced, axial series of tabellae and a periaxial series inclined toward the dissepimentarium.

FIGURED SPECIMENS: T.1524-5 from M.3027; T.1527 from M.3028; Loc. 11, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 6 (rare), 9 (rare), 11 (occasional), 16 (rare), 20 (rare), 24 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The material from Tyers establishes this species as being quite variable in the size of the corallites and the degree of development of carinae. Thus *H.* aff. *approximans* of Hill (1954b) should be included within this species. Hill has pointed to the very close comparison which can be drawn between *H. approximans* and the specimen illustrated as *P. sedgwicki* (Edwards and Haime) by Ma (1937).

Genus *Disphyllum* De Fromentel 1861*Disphyllum cognatum* sp. nov.

(Pl. XXIV, fig. 5, 10; Fig. 4b)

DIAGNOSIS: Phaceloid corals, up to 20 mm in diameter, usually between 50 to 60 septa of both orders, irregularly carinate in the dissepimentarium with major septa attenuated in the narrow tabularium. Septal trabeculae arranged in fans with zone of divergence a few mm within the corallite walls.

DESCRIPTION: Corallum phaceloid, with corallites cylindrical and sub-parallel, up to 20 mm in diameter.

36 septa of both orders present at a diameter of 7 mm increasing to 62 at a diameter of 20 mm, usually about 50 to 60 septa present, with major septa somewhat spindle-shaped, usually attenuated and slightly wavy within the tabularium where they are withdrawn a little from the axis. Minor septa confined to the dissepimentarium, where, with major septa, they are dilated most strongly toward the inner edge so as to form an irregular stereozone in extremely thickened individuals. Septa of both orders typically bearing close, zig-zag carinae formed of trabeculae

divergent from the axial plane of the septa and most strongly developed where the septa are most thickened. Major and minor septa becoming progressively thinner marginally; peripheral stereozone extremely thin.

Dissepimentarium of a moderately wide outer series of about 4 or 5 vertical columns of fairly large, globose, occasionally thickened dissepiments in 3 or 4 vertical columns. Tabularium about 5 mm across, with tabular floors sub-horizontal, and composed of fairly well spaced flat tabellae.

Septal trabeculae arranged in a fan-like series with zone of divergence 2 to 3 mm from the margins of the corallites so that the outer trabeculae are directed outwards; innermost trabeculae almost horizontal.

TYPE SPECIMEN AND OCCURRENCE: Holotype M.3030, T.1536-9, Loc. 19, 24 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: In internal features, this species resembles *Hexagonaria approximans* (Chapman), particularly in the size of the corallites, the nature of the septa and the dissepiments. *H. approximans*, however, possesses fewer septa and the septal trabeculae are directed inwards from the margins of the corallites. In having the zone of divergence of the septal trabeculae within the corallites *D. cognatum* shows a septal structure more typical of the genus *Phacellophyllum* than of *Disphyllum*.

D. cognatum bears a close resemblance to species of North American disphyllids placed in the genus *Cylindrophyllum*. Of these it is most closely allied to *Cylindrophyllum grabaui* Ehler and Stumm (1949, p. 24-5, Pl. 3, fig. 1-4; Pl. 7, fig. 1-5) from the Middle Devonian of the Traverse Group, Michigan, which has similar dilation and carination of the septa, but differs in other respects such as withdrawn major septa, well spaced, often complete tabulae as well as a more usual *Disphyllum* arrangement of the septal trabeculae. By far the closest comparison which can be drawn is with *Disphyllum* (or *Macgeea*) *trochoides* Hill (1942a, p. 249-50, Pl. 8, fig. 5-10) from the Middle Devonian of Burdekin Downs, Fanning R. and Reid Gap, Queensland, which has fewer septa in early growth stages and lacks the characteristic



FIG. 5—*Disphyllum incongruum* sp. nov. (a) T.S., T.1578; (b) L.S., T.1576, both from holotype M.3034. x 3.

septal dilation of *D. cognatum* which gives the spindle-shaped septa. Moreover, *D. trochoides* has the septal trabeculae directed inwards from the margins of the corallites.

***Disphyllum incongruum* sp. nov.**

(Pl. XXIV, fig. 1, 7; Fig. 5)

DIAGNOSIS: *Disphyllum* with extremely thickened peripheral stereozone.

DESCRIPTION: Corallum loosely phaceloid, with corallites cylindrical or slowly expanding, up to 12 mm in diameter.

Usually 56 septa present, well differentiated into major and minor; septa of both orders strongly dilated peripherally in the dissepimentarium. Major septa thin and slightly wavy in the tabularium where their axial ends may be united in a loose axial structure, or they may be slightly withdrawn from the axis. Minor septa extending about one-third of the way to the axis, usually confined to the dissepimentarium or extending a short way into the tabularium.

Dissepimentarium strongly thickened, with up to three series of strongly arched dissepiments present, with largest series toward the periphery of the corallites less thickened; steeply inclined dissepiments may be present along the inner margins of the dissepimentarium. Tabularium of short, somewhat arched, regularly spaced, unthickened tabellae, so that tabular floors have a low, axial swelling.

Septal trabeculae closely spaced, at the margins upwardly inclined at an angle of about 45° and becoming more horizontal axially.

TYPE SPECIMEN AND OCCURRENCE: Holotype M.3034 — T.1574-8, Loc. 21, Limestone Phase, Coopers Creek Formation.

REMARKS: The strong thickening within the dissepimentarium distinguishes this species from other species of *Disphyllum* and recalls rather species of *Plexiphyllum* as have been described by Walther (1928) from the Upper Devonian of Germany. The dissepimentarium however does not possess the single series of horse-shoe plates as in *Plexiphyllum*.

Among Australian species *D. incongruum* approaches *Disphyllum* (or *Macgeea*) *excavatum* Hill (1942a, p. 250-1, Pl. 8, fig. 11-13) from the Middle Devonian of Queensland, which is solitary and has more septa as well as a less dilated dissepimentarium.

***Disphyllum* (?) sp.**

(Pl. XXIV, fig. 2-3)

DESCRIPTION: Solitary (?), cylindrical corals up to 15 mm in diameter with 46 major and minor septa present at a diameter of 10 mm. Septa of both orders strongly dilated within the dissepimentarium, tapering from the periphery where they are most strongly thickened, so that the major septa become attenuated in the tabularium; minor septa extending to the edge of the dissepimentarium. Septa of both orders bearing poorly developed zig-zag carinae. Peripheral stereozone narrow, nowhere thicker than 0.3 mm.

Dissepimentarium of an outer zone of about 5 vertical series of small occasionally thickened dissepiments and an inner zone of about 6 vertical series of larger, more inclined dissepiments. Calyx about 8 mm deep with horizontal or slightly domed tabular floors of either closely spaced tabellae or flat complete tabulae extending across the tabularium.

Septal trabeculae upwardly directed at an angle of about 45° marginally, bending over to almost horizontal toward the axis.

FIGURED SPECIMEN AND OCCURRENCE: T.1541-2, Loc. 11, Limestone Phase, Coopers Creek Formation.

REMARKS: This species possesses zig-zag carinae, as does *D. cognatum* sp. nov. The material, however, is not adequate to fully determine the species even at the generic level.

***Mictophyllum* sp. affin. *M. cresswelli* (Chapman)**

(Pl. XXIII, fig. 3-4)

Affin. *Cyathophyllum cresswelli* Chapman 1925, p. 111, Pl. 13, fig. 11-14.

Affin. *Mictophyllum cresswelli* (Chapman) Hill 1939b, p. 246-8, Pl. 14, fig. 7-11.

Affin. *Mictophyllum* cf. *cresswelli* (Chapman) Hill 1942c, p. 159, Pl. 3, fig. 9.

Affin. *Mictophyllum cresswelli* (Chapman) Hill 1954b, p. 109, Pl. 7, fig. 8a-b.

DESCRIPTION: Large, solitary, cylindrical or sub-trochoid corals up to 35 mm in diameter.

At a diameter of 3 cm, 42 major and 42 minor septa present. Major and minor septa dilated within the dissepimentarium with dilation decreasing from the periphery. Minor septa confined to the dissepimentarium, extending a little over one-third of the distance to the axis. Major septa about twice as long as the minor septa, thin in the tabularium and withdrawn from the axis, somewhat curved. Peripheral stereozone wide, apparently continuous, averaging 2.5 mm in diameter.

Dissepimentarium about 6 mm wide, consisting of about 10 series of small, steeply inclined dissepiments. Tabularium wide, with tabular floors domed, and peripheral tabellae inclined toward the dissepimentarium, made up of numerous, fairly small, arched or flat tabellae. Calyx about 15 mm deep.

FIGURED SPECIMEN AND OCCURRENCE: T.1543-4 from M.3031, Loc. 17, Limestone Phase, Coopers Creek Formation.

REMARKS: This single complete specimen of *Mictophyllum* possesses well-developed minor septa similar to other Australian species. It is closest to *Mictophyllum cresswelli* (Chapman) from which it differs in the greater size and the persistent, wide peripheral stereozone, which is absent in adult stages of *M. cresswelli*. It does resemble closely, however, a specimen figured as such by Hill (1939b, Pl. 14, fig. 10-11) which, for its size, possesses more septa than is usual, as well as a comparatively wide peripheral stereozone, which, nevertheless, is variable in thickness. *M. trochoides* Hill (1940b, p. 265, Pl. 11, fig. 7-10) may possess a similar number of septa for comparable dimensions, but in this species the dilation is even less.

Genus *Thamnophyllum* Penecke 1894

***Thamnophyllum reclinatum* Hill**

(Pl. XXIII, fig. 2; Pl. XXV, fig. 1, 2, 7-10)

?*Diphyphyllum Porteri* var. *mitchellensis* Etheridge 1899b, p. 30, Pl. A, fig. 6-8, 12; Pl. B, fig. 11.

Thamnophyllum reclinatum Hill 1939b, p. 228, Pl. 16, fig. 7-8.

DESCRIPTION: Corallum loosely placeloid with corallites parallel, 3 to 7 mm in diameter, without epitheca, with septa projecting outward as ridges.

24 to 32 septa present, usually poorly differentiated into major and minor septa, although occasional specimens show major septa extending well into the tabularium, inner edge of the dissepimentarium (usually the length of the septa) from one half to three-quarter the radius of the corallites. Septa dilated so that often they may be in contact, particularly toward the peripheral parts of the corallum, sometimes showing a tendency to develop zig-zag carinae.

Dissepimentarium essentially of a single series of small, horse-shoe dissepiments, rarely two series developed; dissepiments varying in size between different corallites, often thickened. Tabularium comparatively narrow, with tabulae rather thickened, well spaced, usually flat or sagging, supplemented at their margins by tabellae.

Septal trabeculae arranged in fans, with zone of divergence coincident with the series of horse-shoe dissepiments; trabeculae outside dissepiments horizontal, about 4 per mm, outer zone up to 2 mm across, but usually between 0.5 and 1 mm.

Only two offsets observed arising from parent corallites with the axils of the branches with irregular dissepimental tissue.

FIGURED SPECIMENS: T.1545 from M.3032, T.1548-9, Loc. 15; T.1546-7, 1550-1, Loc. 20.

OCCURRENCE: Loc. 3 (occasional), 11 (rare), 13 (occasional), 15 (abundant), 19 (rare), 20 (abundant), 21 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: The abundant material from Tyers suggests that this species is particularly variable, and so, in all probability, *Thamnophyllum mitchellensis* (Etheridge) from Sandy's Cr. on the Mitchell R., should be regarded as a synonym. Without reference to topotype material from that locality it is premature to place *T. reclinatum* in synonymy with *T. mitchellensis*.

T. reclinatum is one of the more common of the rugose corals of the Limestone Phase of the Coopers Creek Formation at Tyers. It is confined, however, to certain localities.

Genus *Trapezophyllum* Etheridge 1899

Trapezophyllum elegantulum (Dun)

(Pl. XXV, fig. 11-12)

Cyathophyllum elegantulum Dun 1898, p. 85, Pl. 3, fig. 5-6.

Cyathophyllum ? *elegantulum* Dun, Etheridge 1899b, p. 31, Pl. B, fig. 2-4.

C. (Trapezophyllum) elegantulum Dun, Etheridge 1899b, p. 32.

Trapezophyllum elegantulum (Dun) Hill 1939b, p. 235-6, Pl. 16, fig. 9-11; Stumm 1949b, p. 37, Pl. 17, fig. 21-22.

DESCRIPTION: Corallum cerioid, apparently hemispherical, usually with hexagonal corallites averaging less than 3 mm in diameter. Up to 24 septa in each corallite, with major septa poorly differentiated from minor septa, both orders extending about half-way to the axis of the corallites, thin and somewhat wavy, often slightly thickened at their axial ends.

Dissepiments in two series, with a single, inner series of small, horse-shoe dissepiments developed between the axial ends of the septa, and an outer series of flat or inclined plates, sometimes imbricating. Tabularium about 1.5 mm in diameter with well spaced, flat, slightly thickened tabulae, usually averaging slightly more than 1 mm apart.

FIGURED SPECIMEN AND OCCURRENCE: T.1572-3 from M.3033, Loc. 7, Limestone Phase, Coopers Creek Formation.

REMARKS: Although this single poorly preserved specimen has smaller corallites than is typical for *T. elegantulum*, there is little doubt that it belongs to this species, to date known only from Griffith's Quarry, Loyola. A species of the Australian genus *Trapezophyllum* has recently been described from the Middle Devonian of Germany (Glinski 1955).

Family CRASPEDOPHYLLIDAE Dybowski 1873

Genus *Tipheophyllum* Hill 1956

Hill (1956b) proposed the genus *Tipheophyllum* to include the Australian and New Zealand eridophyllids in which the aulos is imperfectly formed although the tabularium is divided into two regions. In species of *Tipheophyllum* zig-zag carinae are more common than in species of *Eridophyllum*. Stewart (1938) has proposed the genus *Schistotoecholasma*, generally regarded as a synonym of *Eridophyllum*, in which the aulos is imperfectly formed, but in species of *Tipheophyllum* no true aulos is present; the axial ends of the major septa may be slightly dilated and bent but are only rarely confluent.

Tipheophyllum ops sp. nov.

(Pl. XXV, fig. 3-4)

DIAGNOSIS: Solitary (?) *Tipheophyllum* with strongly dilated septa and well spaced tabulae.

DESCRIPTION: Solitary (?), cylindrical or slightly expanding corals up to 17 mm in diameter; epitheca apparently smooth, marked by irregular growth annulations.

Up to 52 septa present, well differentiated into major and minor septa, with minor septa extending about half-way to the axis and major septa withdrawn slightly from the axis to give an extremely imperfect aulos about 2 mm wide. Septa of both orders strongly dilated with thickness decreasing from the margins, although thickened to give rise to an irregular stereozone at the inner edge of the dissepimentarium. Septa of both orders within the dissepimentarium bearing strong, irregularly developed, yard-arm earinae, so that at times the septa appear ragged with internal spaces. Minor septa extending a short distance into the tabularium where the septa are more attenuated; major septa slightly dilated at their axial ends, which may be strongly inflected to give rise to the imperfect aulos. Peripheral stereozone 0.2 mm thick.

Dissepimentarium of 4 to 6 series of small, thickened, globose plates, progressively inclined axially so that usually 2 or 3 more series of highly inclined dissepiments are present along the inner margin of the dissepimentarium. Tabularium divided into two series by the imperfect aulos. Outer series of tabellae upwardly arched from the dissepimentarium, inner series flat or sagging, sometimes complete, tabular floors axially depressed so that within the aulos the level is a few mm lower than the level of the corresponding tabellae of the outer series. Tabellae well spaced about 18 in 5 mm.

Septal trabeculae in general upwardly directed at an angle of 45° at the periphery, becoming more horizontal axially. In excessively dilated regions the trabeculae diverge strongly from the midplane of the septa.

TYPE AND FIGURED SPECIMEN: Holotype M.3035 — T.1579-82, Loc. 15, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 11 (rare), 15 (occasional), Limestone Phase, Coopers Creek Formation.

REMARKS: *Tipheophyllum ops* is most closely allied to *Tipheophyllum bartrumi* (Allan), the common E. Australian and New Zealand species. From this species it differs in possessing fewer, more dilated septa and more distant tabulae. The corals

collected were all solitary and there was no evidence found suggesting that they were ever compound. This possibility, however, cannot be overlooked.

The trivial name is derived from the Latin '*ops*', meaning 'strength'.

Tipheophyllum sp.

(Pl. XXV, fig. 5-6)

DESCRIPTION: Solitary, rapidly expanding, trochoid coral reaching a diameter of 18 mm at 16 mm from the apex.

44 septa of both orders present at a diameter of 14 mm, major and minor septa well differentiated with minor septa extending half-way to the axis and major septa slightly withdrawn from the axis to give an imperfect aulos. Septa strongly dilated with thickness decreasing axially, carinae small and only rarely present.

Dissepimentarium with a wide series of small, thickened, upwardly arched dissepiments which marginally are inclined toward the periphery, and with an inner zone of inclined dissepiments. Tabularium divided into two regions with an inner sagging series of tabellae within the imperfect aulos.

Septal trabeculae arranged in fans with zone of divergence toward the inner margin of the dissepimentarium.

FIGURED SPECIMEN AND OCCURRENCE: T.1588-9, Loc. 15, Limestone Phase, Coopers Creek Formation.

REMARKS: This single, strongly trochoid fragment could be the apical portion of a corallum of *Tipheophyllum ops*, but the nature of the septa and the arrangement of the septal trabeculae suggest that it is a different form.

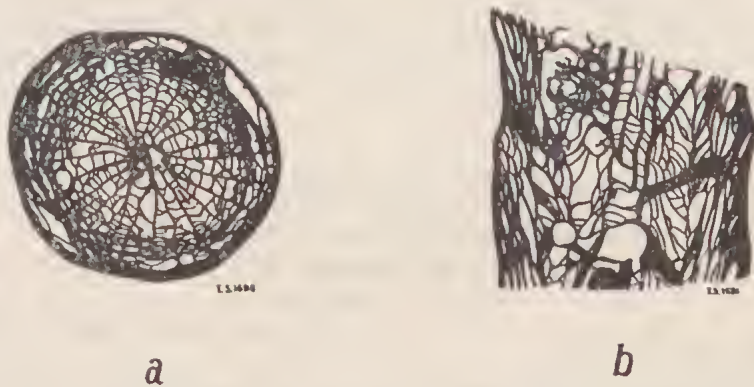


FIG. 6—*Tabulophyllum* (?) *meridionale* sp. nov. (a) T.S., T.1590; (b) L.S., T.1591, both from holotype M.3036. $\times 3$.

Suborder COLUMNARIINA

Family SPONGOPHYLLIDAE Dybowski

Genus *Tabulophyllum* Fenton and Fenton 1924

Following Watkins's (1959) restudy of the type species of the general *Tabulophyllum* Fenton and Fenton and *Diversophyllum* Sloss 1939, it is apparent that *Diversophyllum* should be regarded as a synonym of *Tabulophyllum*.

Tabulophyllum (?) *meridionale* sp. nov.

(Pl. XXVI, fig. 4-5; Fig. 6)

DIAGNOSIS: *Tabulophyllum* with poorly developed minor septa, and major septa amalgamated to give a loose axial structure.

DESCRIPTION: Corallum solitary, cylindrical, attaining a diameter of 15 mm.

50 septa present at a diameter of 14 mm, well differentiated into major and minor septa. Septa of both orders interrupted toward the periphery by lonsdaleoid dissepiments; minor septa rudimentary, usually impersistent, represented in transverse section by trabecular aggregations mounted on the dissepiments, generally confined to the dissepimentarium, but occasionally thin minor septa extend almost to the axis of the corallum. Major septa reaching to the axis of the corallum or withdrawn slightly, axial ends dilated and confluent giving rise to a weak axial structure. Peripheral stereozone narrow, not exceeding 0.5 mm in diameter.

Dissepimentarium up to 4 mm wide with up to 8 series of often thickened, steeply inclined dissepiments. Tabularium of an outer series of strong, upwardly arched tabellae and an inner series of flat tabellae giving rise to a low axial boss a few mm high.

TYPE SPECIMEN AND OCCURRENCE: Holotype M.3036 — T.1590-1, Loc. 15, Limestone Phase, Coopers Creek Formation.

REMARKS: Of the North American Upper Devonian species placed by Fenton and Fenton (1924) in their genus *Tabulophyllum*, *T. meridionale* resembles most closely *T. traversensis* (Winchell), the type species of *Diversophyllum* Sloss 1939. From this species it differs in possessing a wider dissepimentarium and dilation of the axial ends of the major septa to give a loose axial structure.

Solitary spongophyllids are rare in the Devonian of Eastern Australia. *Sino-spongophyllum abrogatum* Hill 1942 has been described from the Lower Devonian Mt Etna Limestone, Queensland. This is the first record of the genus *Tabulophyllum* in Eastern Australia, although Hill (1954a) records the genus from the Upper Devonian of Western Australia.

Family PTENOPHYLLIDAE Wedekind

Genus *Acanthophyllum* Dybowski 1873*Acanthophyllum aequiseptatum* Hill

(Pl. XXVI, fig. 2-3)

Acanthophyllum aequiseptatum Hill 1941, p. 251, Pl. 9, fig. 1-2; Hill 1942d, Pl. 6, fig. 1a-b; Hill 1950, p. 139, Pl. 5, fig. 1.

DESCRIPTION: Corallum loosely phaceloid, with corallites cylindrical to subtrochoid, up to 15 mm in diameter.

Between 56 and 60 septa of both orders present in adult corallites, with minor septa extending to the inner margin of the wide dissepimentarium (i.e. about three-quarters of the distance to the axis of the corallites) and the major septa extending almost to the axis. Septa of both orders dilated throughout their length, thickening greatest at their base where they are in contact, giving rise to a peripheral stereozone up to 1.5 mm wide. Septa of both orders comparatively straight, in places irregularly carinate, particularly the major septa within the tabularium.

Dissepimentarium wide, consisting of about 10 series of comparatively small, often thickened dissepiments which become progressively inclined axially. Tabu-

larium narrow, with marginally sagging tabellae which give rise to depressed tabular floors.

FIGURED SPECIMEN AND OCCURRENCE: T.1592-3, Loc. 3, Limestone Phase, Coopers Creek Formation.

REMARKS: This single, poorly preserved fragment of a phaceloid corallum agrees in all essential features with *A. acquiseptatum* which Hill originally described from the Middle Devonian of Taemas, N.S.W. The corallite diameter is somewhat smaller than in the holotype but is similar to the phaceloid specimen illustrated by Hill (1942d) from Wellington District, N.S.W., again from rocks regarded as Middle Devonian in age.

Acanthophyllum clermontensis (Etheridge)

(Pl. XXVII, fig. 1-2)

Cyathophyllum ? *clermontensis* Etheridge 1911, p. 5, Pl. B, fig. 1-2; Pl. D, fig. 3.

Acanthophyllum clermontensis (Etheridge) Hill 1939c, p. 57-8, Pl. 4, fig. 1-2; ? Pl. 4, fig. 3-5.

Acanthophyllum ? *clermontense* (Etheridge) Hill 1941, p. 252-3, Pl. 9, fig. 5.

Acanthophyllum affin. *clermontense* (Etheridge) Hill 1950, p. 139, Pl. 5, fig. 3a-b.

DESCRIPTION: Large, solitary (?), slightly ovate, sub-cylindrical corals up to 6 cm in diameter and at least 15 cm in height.

104 septa present at a diameter of 6 cm, well differentiated into major and minor septa. Septa of both orders slightly carinate, straight and dilated within the dissepimentarium, with the major septa slightly more thickened than the minor septa. A peripheral zone a few mm wide, in which the septa are attenuated, is sporadically developed. Major septa extending unequally to the axis, attenuated at the inner edge of the dissepimentarium, but often thickening again toward their axial ends which are irregularly curved and confluent. Minor septa tapering throughout their length, usually extending two-thirds to three-quarters the radius of the corallum. Peripheral stereozone about 0.5 mm wide.

Dissepimentarium wide, consisting of about 30 vertical series of fairly small, often thickened dissepiments which become progressively inclined toward the inner edge of the dissepimentarium. In transverse section the dissepiments become geniculate toward the periphery where, in the undilated zones, they may become almost naotic. Lateral dissepiments lining the sides of the septa common.

Tabularium one-third to one-quarter the diameter of the corallum, consisting of fairly closely spaced, somewhat upwardly arched tabellae, giving rise to slightly domed tabular floors.

FIGURED SPECIMEN AND OCCURRENCE: M.3037 — T.1599, 1600, Loc. 20, Limestone Phase, Coopers Creek Formation.

REMARKS: The most noticeable difference between this single specimen from Tyers and the syntype figured by Hill (1939c, Pl. 4, fig. 1) is in the greater number of septa and their more uniform dilation in the Tyers specimen. The Tyers specimen possesses over 20 more septa than the figured syntype but it is almost twice the size. Etheridge's and Hill's figures show that in *A. clermontensis* the number of septa increases as the coral expands. Thus at a diameter of 15 mm there are approximately 50 septa (Etheridge, Pl. B, fig. 2), at 35 mm there are 70 septa (Etheridge, Pl. B, fig. 1), and at 80 mm (inferred) there are about 80 septa (Hill, Pl. 4, fig. 1). Extrapolation of this suggests that a specimen comparable in diameter to the Tyers specimen would have about 100 septa. On the other hand species such as *Acanthophyllum mansfieldense* (Dun) possess a stable number of septa in expanding from 1 cm to 4 cm.

In the Tyers specimen the major septa tend to meet at the axis rather than twist vortically within the tabularium as in the figured syntype mentioned above. This is of little taxonomic importance as Smith (1945, Pl. 6, fig. 1-2) has illustrated similar variation in *A. heterophyllum* (Edwards and Hainie), the type species of *Acanthophyllum*.

It is noteworthy the *A. clermontensis* occurs in a fauna which is best regarded as of basal Lower Devonian age. Hill (1939c), in revising Etheridge's (1911) work on the rugose corals of the Clermont District, Queensland, regarded the small fauna as Upper Couvinian in age. This was based largely on the similarity between *A. clermontensis* and European ptenophyllids.

Acanthophyllum mansfieldense (Dun)

(Pl. XXVI, fig. 11-12)

Cyathophyllum mansfieldense Dun 1898, p. 87, Pl. 3, fig. 3-4.

Acanthophyllum mansfieldense (Dun) Hill 1939b, p. 223-4, Pl. 15, fig. 1-3.

Acanthophyllum sp. cf. *mansfieldense* (Dun) Hill 1940a, Pl. 2, fig. 1a-b.

Acanthophyllum ? *mansfieldense* (Dun) Hill 1942c, p. 146, Pl. 2, fig. 1.

Acanthophyllum cf. *mansfieldense* (Dun) Hill 1942d, Pl. 5, fig. 1.

DESCRIPTION: Cylindrical to sub-trochoid solitary corals up to 4 cm in diameter; largest corallum fragmentary, at least 8 cm high.

In general 52 septa present from diameter of 1 cm to 4 cm, well differentiated into major and minor septa. Septa of both orders usually strongly dilated in the dissepimentarium with thickening decreasing toward the tabularium, often with wedge-shaped steps which are apparently formed from thickened carinae; occasional specimens show more uniformly tapering septa which may then bear irregular carinae and lateral dissepiments; in such specimens a sporadically developed undilated peripheral zone a few mm wide may also be present. The major septa extend unequally into the tabularium, are withdrawn from the axis in younger specimens, and often slightly dilated toward their axial ends which may be waved. Major septa in the tabularium and the more attenuated axial ends of the minor septa usually irregularly carinate. Minor septa extending to the inner edge of the dissepimentarium, about three-quarters of the distance to the axis of the corallum.

Dissepimentarium wide, consisting of up to 16 vertical series of fairly small, thickened dissepiments peripherally inclined at an angle of about 45° but steepening toward the inner margin of the dissepimentarium; in transverse sections they are frequently geniculate toward the periphery. Tabularium between two-thirds and three-quarters of the diameter of the corallum, consisting of sagging, closely spaced tabellae.

FIGURED SPECIMEN: T.1601-2 from M.3038, Loc. 20, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (occasional), 19 (occasional), 20 (occasional), 21 (rare), 27 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The material from Tyers suggests that this species is variable in the thickening of the septa, with certain specimens approaching *A. aquiseptatum* in their appearance. One such specimen (T. 1596-7, Loc. 3), doubtfully included in the species, is illustrated (Pl. XXVI, fig. 9-10). The more thickened specimens resemble closely *Acanthophyllum baculoides* (Barrande) (Pořta 1902, from the Koněprus; Le Maitre 1934, from the limestones of Chalonnès transitional between the Lower and Middle Devonian) which has, however, more septa.

Acanthophyllum sweeti (Etheridge)

(Pl. XXVI, fig. 7-8)

Cyathophyllum sp. indet. Etheridge 1892b, p. 59, Pl. 3, fig. 11-12.*Cyathophyllum Sweeti* Etheridge 1895, p. 521, Pl. 40, fig. 3-4; Pl. 41, fig. 1.*Acanthophyllum sweeti* (Etheridge) Hill 1942a, p. 235-6, Pl. 5, fig. 1-5.

DESCRIPTION: Corallum solitary and sub-cylindrical, up to 20 mm in diameter.

52 septa present at a diameter of 17 mm, differentiated into major and minor septa. Septa of both orders somewhat irregular and with irregular carinae present particularly toward their axial ends, regularly dilated and toward the periphery expanding suddenly to give a crenulate peripheral stereozone. Major septa extend unequally toward the axis, somewhat wavy in the tabularium with ends dilated and spatulate; one major septum (counter septum ?) extends right to the axis. Minor septa reach about three-quarters of the distance to the axis.

Calyx with outer surface of the dissepimentarium horizontal, progressively inclined toward the tabularium, strongly thickened in certain zones parallel to the outline of the calyx, apparently representing the position of the calyx in earlier growth stages. Dissepimentarium of about 15 series of small, somewhat arched dissepiments which become steeply inclined toward the inner margins of the dissepimentarium. Tabularium of closely spaced parallel tabellae sagging axially.

FIGURED SPECIMEN AND OCCURRENCE: T.1606-7, Loc. 15, Limestone Phase, Coopers Creek Formation.

REMARKS: This single specimen closely resembles *A. sweeti* (Etheridge) from the Upper Middle Devonian of Burdekin Downs, Fanning R. and Reid Gap, Queensland, but although possessing the same number of septa as this species it is much larger than is typical and the septa are less carinate and are more regular. In the absence of further material it is included in *A. sweeti*.

In the transverse section illustrated an irregular stereozone is present within the dissepimentarium. This is apparently caused by the strong thickening in zones within the dissepimentarium which represent the position of the calyx in early growth stages of the corallum.

Genus *Dohmophyllum* Wedekind 1923*Dohmophyllum pridianum* sp. nov.

(Pl. XXVIII, fig. 8-9)

DIAGNOSIS: *Dohmophyllum* with carinate septa, a comparatively narrow dissepimentarium and short minor septa.

DESCRIPTION: Corallum solitary, sub-cylindrical, and somewhat ovate in transverse section, reaching a diameter of 3 cm and a height of at least 7 cm.

58 septa present at a diameter of 3 cm, well differentiated into major and minor septa. Septa of both orders strongly dilated within the narrow dissepimentarium, tapering toward the axis, dilated suddenly toward the periphery to give a peripheral stereozone 1.5 to 2.5 mm wide. Septa of both orders bearing irregular zig-zag carinae, which are large where the septa are thickened, but where the major septa are attenuated in the tabularium the carinae are represented by small irregular projections roughening the sides of the septa. Major septa wavy and broken within the tabularium, extending unequally toward the axis. Minor septa extending to the inner edge of the dissepimentarium, about one-third the way to the axis of the corallum.

Dissepimentarium narrow, with about 5 series of steeply inclined dissepiments which are thickened at definite levels. Tabularium of small, well-spaced tabellae which are upwardly arched to give a broad, axial swelling in the tabular floors. Septal trabeculae almost horizontal, with only a slight upward inclination.

TYPE SPECIMEN AND OCCURRENCE: Holotype M.3039 — T.1613-6, Loc. 13, Limestone Phase, Coopers Creek Formation.

REMARKS: This species resembles the species of *Dohmophyllum* with carinate septa included by Wedekind (1923, 24) in his genus *Trematophyllum*. It differs from the German Middle Devonian species chiefly in the comparatively narrow dissepimentarium and concomitantly short minor septa. The axial ends of the major septa in the holotype are broken within the tabularium, a feature which may be seen in other species of *Dohmophyllum*.

Genus *Xystriphyllum* Hill 1939

Xystriphyllum mitchelli (Etheridge)

(Pl. XXVI, fig. 1, 6)

Cyathophyllum mitchelli Etheridge 1892a, p. 172, Pl. 1, fig. 9-10; Pl. 12, fig. 4.

Xystriphyllum mitchelli (Etheridge) Hill 1939c, p. 63; Hill 1941, p. 269, Pl. 11, fig. 2-3; Hill 1942c, p. 147, Pl. 2, fig. 9; Hill 1950, p. 140, Pl. 5, fig. 5-6.

DESCRIPTION: Corallum hemispherical, up to 6 cm in diameter, with corallites cerioid, attaining 7 mm in maximum diameter, usually averaging about 5 mm.

Up to 42 septa present, with major septa extending to the axis of the corallites or irregularly withdrawn and minor septa extending half-way to the axis or less, in places irregularly carinate. Septa of both orders marginally dilated with dilation decreasing toward their free ends, major septa within the tabularium thin and slightly wavy. Septa dilated at their bases to give a peripheral stereozone up to 0.4 mm thick.

Dissepimentarium extending half-way to the axis with up to 5 series of unthickened, inclined dissepiments. Tabularium about 2.5 mm wide with tabular floors horizontal or sagging, with closely spaced tabellae.

FIGURED SPECIMEN AND OCCURRENCE: T.1534-5 from M.3029, Loc. 11, Limestone Phase, Coopers Creek Formation.

REMARKS: *Xystriphyllum manipulatam* (Pošta 1902, Pl. 103, fig. 3, Pl. 104, fig. 6-7) from the Lower Devonian Koněprus Limestone is a form identical with *X. mitchelli* (Eth.). *Hexagonaria pachythea* Gliniski (1955, p. 90-3, Fig. 11, 12, 14) from the Eifel Middle Devonian probably represents a closely related European species of *Xystriphyllum* with larger corallite diameter. Many of the Devonian species described from Siberia by Bulvankov and Zhnev (in Halpina 1955) in the genus *Stenophyllum* appear to be species of *Xystriphyllum*.

Genus *Lyriellasma* Hill 1939

Lyriellasma subcaespitosum (Chapman)

(Pl. XXVIII, fig. 6-7, 11-12)

Cyathophyllum subcaespitosum Chapman 1925, p. 112, Pl. 18, fig. 15a-b, 16.

Lyriellasma subcaespitosum (Chapman) Hill 1939b, p. 244-6, Pl. 14, fig. 1-6; Pl. 15, fig. 6-7; Stumm 1949, p. 34, Pl. 16, fig. 1-2.

Lyriellasma ? *subcaespitosum* (Chapman) Hill 1954b, p. 111, Pl. 7, fig. 14a-b.

Lyriellasma subcaespitosum (Chapman) Hill 1956a, F. 306, fig. 208, 1a-c.

Lyriellasma subcaespitosum praecursor subsp. nov.

(Pl. XXVIII, fig. 11-12; Fig. 7)

Lyriellasma subcaespitosum (Chapman) Hill 1939b, p. 244-6 (*partim*).? *Lyriellasma* ? *subcaespitosum* (Chapman) Hill 1954b, p. 111, Pl. 7, fig. 14a-b.

DIAGNOSIS: *L. subcaespitosum* with large corallite diameter, regular peripheral stereozones and long counter septa.



FIG. 7—*Lyriellasma subcaespitosum praecursor* subsp. nov. (a) T.S., (b) L.S.
Drawings made from various slides cut from the holotype M.3040. $\times 3$.

DESCRIPTION: Phaceloid corallum with corallites up to 20 mm in diameter, adult corallites averaging about 12 mm.

Up to 62 septa present, differentiated into major and minor septa with major septa usually more dilated than minor septa and extending irregularly to the axes of the corallites, with one septum (the counter ?) usually longer than the rest. Septa of both orders comparatively straight, although major septa within the tabularium often bent toward the plane of the cardinal and counter septa. Minor septa extending about half-way to the axis, often interrupted and broken into discrete trabeculae mounted on dissepiments. Septa of both orders often lonsdaleoid in adult corallites, particularly the thin minor septa. Septa dilated at their base to give a regular peripheral stereozone 1.5 to 4 mm wide in different corallites, usually about 2 mm.

Dissepimentarium comparatively narrow, consisting of 3 to 5 vertical series of inclined dissepiments often thickened at particular levels. Tabularium of widely spaced depressed tabellae giving funnel-shaped tabular floors.

TYPE SPECIMEN: M.3040 — T.1619-25, Loc. 15, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 15 (occasional), 20 (rare), 21 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The differences between the new subspecies and *Lyriellasma subcaespitosum* S.S. are slight, but as the two can be adequately distinguished it is best to separate the Tyers form in the interests of stratigraphic precision. *L. subcaespitosum praecursor* differs from *L. subcaespitosum* S.S. in its generally larger size, the more regular peripheral stereozone which is slightly narrower, the absence of carinae on the septa and the longer counter septa. The minor septa are in general slightly less well developed and the incidence of lonsdaleoid dissepiments is higher. Another minor difference is that the thickening of the dissepiments in zones within the dissepimentarium is not so marked, nor does it extend to the inner margin of the dissepimentarium. This can be seen well in Pl. XXVIII, fig. 7 where a typical corallite of *L. subcaespitosum* S.S. from the Lilydale Limestone is illustrated for comparison.

The differences listed above are all differences of degree and all the corallites within a corallum do not show them; regardless it is possible to distinguish the subspecies on examination of a number of corallites within a corallum. Thus *L. subcaespitosum* S.S. is known only from the Lilydale Limestone, while the new subspecies includes the form from Loyola discussed by Hill (1939b, p. 245; 1954b, p. 111). The single corallites described from Waratah Bay by Hill (1954c) probably belong to the new subspecies.

An interesting specimen of *L. subcaespitosum* S.S. was found in the material from the Lilydale Limestone sectioned whilst building up a reference collection from that locality. This shows the increase of *L. subcaespitosum* in this case to be peripheral with a circlet of young corallites arising from the widely lonsdaleoid dissepimentarium of the parent corallite, the inner margin of which eventually becomes the epitheca of the parent corallite (Pl. XXVIII, fig. 6).

Suborder CYSTIPHYLLINA Nicholson

Family TRYPLASMATIDAE Etheridge

Genus *Tryplasma* Lonsdale 1845

Tryplasma columnare Etheridge

(Pl. XXVIII, fig. 4-5)

Tryplasma columnaris Etheridge 1907, p. 85, Pl. 15, fig. 6; Pl. 19, fig. 5; Pl. 24, fig. 2-5.

Tryplasma columnare Etheridge, Hill and Jones 1940, p. 187-8, Pl. 3, fig. 3-4.

DESCRIPTION: Corallum solitary, cylindrical, attaining 15 mm in diameter, with about 70 short septa poorly differentiated into major and minor, although the major septa are usually longer and extend up to 3 mm into the lumen. Septal trabeculae embedded in lamellar stereome at the base of the septa to give a peripheral stereozone between 1 and 2 mm wide. Septa acanthine along their free edge, breaking into short, upwardly directed spines each consisting of a single rhabdacanthine trabecula.

Tabulae thin, horizontal, usually complete and often bearing short trabeculae, irregularly spaced but averaging about 1 mm apart.

FIGURED SPECIMEN AND OCCURRENCE: T.1639-40, Loc. 5, Limestone Phase, Coopers Creek Formation.

REMARKS: The single specimen from Tyers possesses slightly shorter septa than is typical of *T. columnare* but otherwise it agrees closely with the description furnished by Etheridge (1907) and Hill and Jones (1940).

Tryplasma etheridgei sp. nov.

(Pl. XXIX, fig. 2, 4, 6, 8)

DIAGNOSIS: Small *Tryplasma* with long, acanthine major septa, extremely short minor septa and closely spaced, sub-horizontal tabulae.

DESCRIPTION: Solitary (?), cylindrical corallum up to 5 mm in diameter. Epitheca marked by faint septal ridges and growth annulations.

Up to 26 mm long; fairly thick major septa present at a diameter of 5 mm and extending irregularly toward the axis. Septal trabeculae enveloped at the base of the septa by lamellar stereome giving a peripheral stereozone 0.5 to 1 mm wide. Major septa strongly acanthine along their free edge for the last quarter of their length, with spines progressively more upwardly directed axially. Minor septa extremely short, represented by trabeculae embedded in the peripheral stereozone, only very rarely extending into the lumen.

Tabulae thin and flexed, horizontal or slightly domed axially, complete and evenly spaced usually at about 4 per mm, but more in some coralla.

TYPE SPECIMEN AND OCCURRENCE: Holotype—T.1633-4, Loc. 50, Boola Beds; also figured T.1635-6, same locality.

REMARKS: *T. etheridgei* bears little relationship to other described Australian species of *Tryplasma*. Of the overseas species it resembles most closely *Tryplasma malverense* Hill (1936, p. 208-9, fig. 25, 33, 48-49), from the Wenlock Limestone. This species, however, is somewhat larger and has fewer septa and lacks the marked inequality in size between the major and minor septa.

The fine structure of the septa is not well preserved in the material examined but apparently the septal trabeculae are rhabdacanthine.

Tryplasma wellingtonensis Etheridge

(Pl. XXIX, fig. 1, 3)

Tryplasma wellingtonensis Etheridge 1895, p. 160; Etheridge 1907, p. 89, Pl. 16, fig. 5-10; Pl. 21, fig. 11-12; Pl. 22, fig. 2-4; Hill 1942d, p. 187, Pl. 5, fig. 10; Hill 1954b, p. 112, Pl. 8, fig. 16a-b.

DESCRIPTION: Corallum solitary, up to 14 mm in diameter where there are about 60 septa present. Major septa extending about half-way to the axis or slightly less with minor septa about half as long, with septa of both orders usually acanthine axially. Septal trabeculae rhabdacanthine, enveloped in lamellar stereome, marginally giving rise to a peripheral stereozone up to 2.5 mm wide. Tabulae thin, sub-horizontal, somewhat flexed, averaging about 2 mm apart.

FIGURED SPECIMENS: T.1643, Loc. 3; T.1644, Loc. 21, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (occasional), 20 (rare), 21 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: *Tryplasma wellingtonensis* closely resembles *T. radícula* Rominger (Stumm 1952, p. 842, Pl. 125, fig. 1-9), from the Middle Silurian of Michigan and Iowa. It also can be compared with *Stortophyllum* affn. *simplex* Wedekind of Soshkina (1937, p. 43, fig. 1-2) from the Upper Silurian of the Urals.

Tryplasma sp. A

(Pl. XXVIII, fig. 3, 10)

DESCRIPTION: Corallum solitary, cylindrical, up to 2 cm in diameter, where 80 septa are present. Septa well differentiated into major and minor septa. Major septa

thick, extending unevenly to the axis of the corallum, acanthine along their free edge with large, rhabdacanthine septal trabeculae upwardly directed at an angle of about 20° marginally but increasing to almost vertical axially where discrete spines may be mounted on the tabulae. Minor septa short, up to 3 mm long, equal in length to the width of the peripheral stereozone.

Tabulae often thickened, usually complete, slightly sagging, in certain specimens crowded toward the calyx, usually averaging about 2 mm apart.

FIGURED SPECIMENS: T.1646, Loc. 15, T.1647, Loc. 22, Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 3 (occasional), 15 (rare), 20 (rare), 22 (rare), Limestone Phase, Coopers Creek Formation.

REMARKS: The extremely long, coarsely trabeculate major septa serve to distinguish this species from other Australian tryplasmids. I have not seen descriptions of any closely comparable overseas species. Although this species is not uncommon in the limestone at Tyers, the material collected was fragmentary and not really suitable on which to base a new species.

Tryplasma sp. B

(Pl. XXIX, fig. 5, 7)

DESCRIPTION: Corallum up to 20 mm in diameter and up to 10 cm high. Epitheca marked by longitudinal septal ridges and irregular growth annulations.

About 70 short septa present at a diameter of 15 mm, with major septa slightly longer than minor septa, projecting as short spines from the peripheral stereozone up to 3 mm wide. Tabulae well spaced, usually horizontal and complete and often thickened by lamellar stereome, usually averaging about 2 mm apart, but often with a tabula resting for much of its width on a lower tabula.

FIGURED SPECIMEN AND OCCURRENCE: T.1648-9, Loc. 48, Boola Beds.

REMARKS: This form is apparently different from the other Australian species of *Tryplasma* of comparable dimensions. It could be close to the imperfectly known *T. murrayi* Etheridge (1907, p. 93) from Waratah Bay.

Certain coralla from Loc. 48, associated with *Tryplasma* sp. B, although possessing similar external characteristics, possess a thinner stereozone and regular, unthickened tabulae. These could represent a further species of *Tryplasma* but further material is necessary before they can be separated with confidence from *Tryplasma* sp. B.

The septal trabeculae of this species are well-spaced rhabdacanths which in places have recrystallized to give holacanths.

Family CYSTIPHYLLIDAE Edwards and Haime

Genus *Microplasma* Dybowski 1873

Microplasma sp. cf. *M. devonica* Soshkina

(Pl. XXVII, fig. 13, Pl. XXIX, fig. 2, 6)

Cf. *Microplasma devonica* Soshkina 1937, p. 79-80, Pl. 15, fig. 5-6.

DESCRIPTION: Solitary (?), cylindrical corals up to 8 mm in diameter with epitheca marked by irregular growth annulations. Peripheral stereozone up to 1 mm wide, apparently made up of trabeculae representing the septa. Horizontal skeletal elements large, in certain specimens differentiated into a peripheral series of inclined dissepiments and an axial series of upwardly arched tabulae; in other

specimens not clearly differentiated with lumen filled by two or three series of unthickened globose plates.

FIGURED SPECIMEN AND OCCURRENCE: T.1635-6; T.1670, Loc. 50, Boola Beds.

REMARKS: In the specimens of this form available for study, the preservation is such that it is very difficult to establish positively the trabecular nature of the peripheral stereozone. Although most of the specimens are apparently solitary the juxtaposition of coralla in one section suggests a phaceloid growth habit.

The holotype of *M. devonica* Soshkina, from the slopes of the Urals, falls within the range of variation of the material from Tyers, but the rather poor preservation of the Tyers specimens prevents positive identification with Soshkina's species. *M. devonica* was described from rocks regarded by Soshkina as being of Coblenzian age.

Among Australian species *M. devonica* resembles most closely '*Cystiphyllum conjunctum* Hill (1942d, p. 185, Pl. 5, fig. 3a-b) from the Wellington district, N.S.W., but this species in its gross morphology is more closely allied to *M. nestlerowskii* Peetz.

Genus *Cystiphyllum* Lonsdale 1839

'*Cystiphyllum*' sp. affin. '*C.*' *australe* Etheridge

(Pl. XXVIII, fig. 1-2)

Affin. *Cystiphyllum americanum* Edwards and Haime, var. *australe* Etheridge 1892, p. 58, Pl. 3, fig. 13-14.

Affin. '*Cystiphyllum*' *australe* Etheridge, Hill 1942a, p. 243-4, Pl. 6, fig. 10-13.

DESCRIPTION: Corallum solitary, up to 25 mm in diameter with peripheral stereozone up to 3 mm wide in which are present short, closely spaced trabeculae, which may extend on to the outer dissepiments. Tabularium about half the width of the corallum, poorly differentiated from the dissepimentarium. The plates of the dissepimentarium are smaller, more inclined and less arched than those of the tabularium. Slight dilation of the dissepiments is present in certain zones within the corallum.

FIGURED SPECIMEN AND OCCURRENCE: T.1672-3, Loc. 13, Limestone Phase, Coopers Creek Formation.

REMARKS: This form agrees closely with '*C.*' *australe* Etheridge from the Middle Devonian of Queensland, except that the peripheral stereozone is much wider and there are present very poorly developed zones of skeletal dilation. '*Cystiphyllum*' sp. of Hill (1939b), from Loyola, could represent a similar form.

Hill (1942a) has suggested possible relationships of '*Cystiphyllum*' *australe* to overseas species.

Other fragmentary cystimorphs were encountered in thin section from various localities. These are recorded in Table 1 as '*Cystiphyllum*' spp.

Family GONIOPHYLLIDAE Dybowski

Genus *Rhizophyllum* Lindström 1866

Rhizophyllum (?) sp.

(Pl. XXI, fig. 7)

One fairly large internal mould of a calceoloid corallum (M. 3042) was collected from Loc. 48, Boola Beds. This measured 10 mm high with an aperture of 17 x 10 mm. Without more material positive identification of this specimen is impossible.

PHYLUM BRACHIOPODA

Class ARTICULATA

With constant elevation of the taxonomic categories of articulate brachiopods, in present classifications (e.g. Muir-Wood 1955) the anomalous situation is found of the separation of punctate and impunctate members of a particular group at the suborder level e.g. Orthoidea and Dahmannelloidea, and it is at this level that the other main brachiopod groups are separated e.g. Spiriferoidea. Clearly this scheme does not reflect the true relations within the Articulata, even admitting the doubtful supposition that punctation has arisen but once in each stock. In the descriptions below the classification is carried only to the superfamily level.

Superfamily ORTHACEA Walcott and Schuchert

Family ORTHIDAE Woodward

Genus *Dolerorthis* Schuchert & Cooper 1931*Dolerorthis persculpta* sp. nov.

(Pl. XXX, fig. 1-6; Fig. 8)

DIAGNOSIS: *Dolerorthis* with strong radial ornament, comparatively high dorsal interarea, and small ventral muscle area.

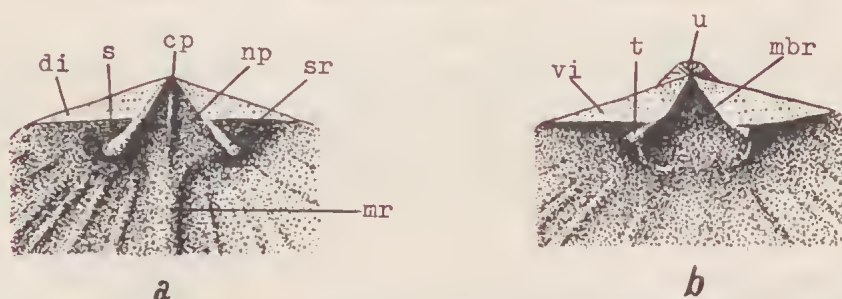


FIG. 8—*Dolerorthis persculpta* sp. nov. (a) Dorsal interior drawn from latex impression of holotype M.3416; (b) Ventral interior based on latex impressions of M.3417-20. di: dorsal interarea, cp: cardinal process, np: notothyrial platform, s: socket, sr: socket ridge, mr: median ridge, mbr: muscle bounding ridge, t: teeth, u: umbo, vi: ventral interarea. $\times 5$ approx.

DESCRIPTION:

EXTERIOR—Outline subquadrate, with greatest width half-way between mid-length of shell and the long hingeline; shell unequally biconvex with ventral valve more strongly arched. Dorsal valve with a sharp, strong sulcus which flattens anteriorly so that the anterior commissure is broadly sulcate. Ventral interarea plane or slightly concave, higher than dorsal interarea, and apsacline. Dorsal interarea plane with a faint furrow running from the umbo just outside the notothyrium; from strongly anacline to orthocline. Ventral umbo more strongly incurved than the dorsal umbo. Delthyrium and notothyrium open.

Surface ornament of strong, fascicostellate ribs, which are crossed by fine, closely spaced growth ridges. Each valve bearing about 35 costae which marginally are spaced at about 2 per mm.

VENTRAL INTERIOR—Delthyrial cavity comparatively deep, bounded laterally by the weak dental lamellae or their anterior continuation on the floor of the valve as weak muscle bounding ridges. Teeth moderately strong, triangular, and placed laterally from the delthyrial margin, supported by weak, receding dental lamellae. Muscle area small, triangular and extending only a short distance anterior from the teeth, not clearly differentiated into adductors and diductors, but presumably with the narrow adductors extending to the front of the muscle area.

DORSAL INTERIOR—Notothyrial cavity shallow, with a high notothyrial platform which is continued anteriorly as a median ridge. Cardinal process long and linear, mounted on the notothyrial platform, and lacking subsidiary ridges. Inner socket ridges short, somewhat bladed, and outlining comparatively shallow sockets. Dorsal musculature not apparent.

[The term 'socket ridges' or 'inner socket ridges' is to be preferred to the term 'brachio-phores' of Schuchert and Cooper (1932) in describing the outgrowths of cardinalia anteriorly bounding the sockets in orthacids, dalmanellacids, and certain strophomenacids, as this latter term implies false homologies with the crural bases of such groups as the rhynchonellacids. In orthacids and dalmanellacids it is extremely doubtful whether these structures could have served as lophophore supports (*vide* Williams 1956, p. 263 *et seq.*)]

MEASUREMENTS: M.3416, l. = 13 mm, w. = 15 mm.

TYPE AND FIGURED SPECIMENS: Holotype M. 3416 (dorsal valve); M.3417—both from Loc. 47, Boola Beds; M.3415, Loc. 48, Boola Beds.

OCCURRENCE: Loc. 47 (occasional), 49 (occasional), Boola Beds.

REMARKS: The surface ornament, the receding dental lamellae and the teeth placed laterally from the delthyrial margins, as well as details of the cardinalia ally this species with those included in the North American and European Silurian genus *Dolerorthis*. Externally it perhaps resembles most closely '*Schizorammina*' *nisis* (Hall and Whitfeld) (Schuchert and Cooper 1932, Pl. 5, fig. 11, 16) but *D. persculpta* is a larger and proportionately wider form.

Superfamily DALMANELLACEA

Family ONNIELLIDAE Öpik

Genus *Onniella* Bancroft 1928

(= ? *Dalmanella* Hall and Clarke 1892 *sensu* Schuchert and Cooper 1932)

Onniella (?) *tyersensis* sp. nov.

(Pl. XXX, fig. 7-11; Fig. 9)

DIAGNOSIS: Small, biconvex *Onniella* with wide median separation of the dorsal muscle field, and possessing a long-shafted cardinal process with a large, bilobed myophore.

DESCRIPTION:

EXTERIOR—Outline subcircular, with greatest width about midlength of the shell; both valves evenly convex, but with a higher interarea on the ventral valve. A faint sulcus may be present in the posterior of the dorsal valve, but it fades anteriorly so that the anterior commissure is usually rounded. Interareas plane, with ventral interarea apsacline, dorsal interarea anacline; delthyrium and notothyrium open.

Surface ornament fascicostellate, with each valve bearing about 40 costellae, marginally spaced at about 4 or 5 per mm. Costellae crossed by irregularly spaced, concentric growth lines.

VENTRAL INTERIOR—Delthyrial cavity comparatively deep, bounded by short, vertical, receding dental lamellae. Teeth moderately strong, triangular, with poorly defined 'socket ridge fossettes'. Dental lamellae continued anteriorly as a poorly defined muscle bounding ridge. Ventral muscle area not incised, triangular and extending only a short distance anteriorly from the base of the dental lamellae.

DORSAL INTERIOR—Inner socket ridges comparatively heavy, somewhat cylindrical, anteriorly outlining deep sockets which posteriorly are defined by short swellings below the dorsal interarea, extending the length of the socket and widening laterally. Cardinal process in general with a bilobed myophore filling the notothyrial cavity, and supported by a long shaft which usually extends well down the low wide median ridge which separates the adductors. The muscle impressions are poorly defined but suggest widely separated elliptical adductors in which the separation into anterior and posterior pairs is not visible.

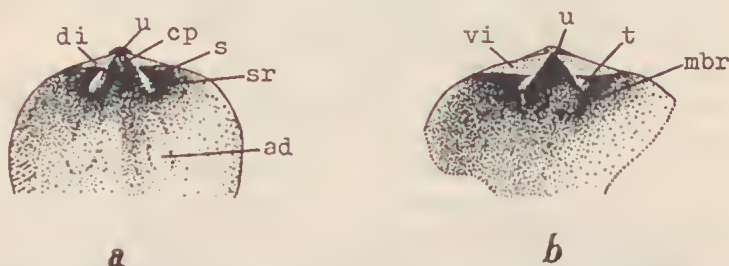


FIG. 9—*Onniella* (?) *tyersensis* sp. nov. (a) Dorsal interior drawn from latex impression of holotype M.3424; (b) Ventral interior drawn from latex impression of M.3425. cp: cardinal process, di: dorsal interarea, ad: adductor impressions, s: socket, sr: socket ridge, u: umbo, t: tooth, vi: ventral interarea, mbr: muscle bounding ridge. $\times 5$ approx.

MEASUREMENTS: M.3424, l. = 7 mm, w. = 7 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3424 (dorsal valve), M.3421-3, all from Loc. 43, Boola Beds.

OCCURRENCE: Loc. 40 (rare), 43 (common), 47 (rare), Boola Beds.

REMARKS: There exists a certain amount of confusion in the generic naming of dalmanellacids, initiated by Schuchert and Cooper (1932) in their interpretation of *Dalmanella* Hall and Clarke, for they took as type of the genus *Dalmanella testudinaria* of Hall and Clarke, not Dalman. Öpik (1933) pointed to the error of this procedure, and claimed that the large number of species referred to *Dalmanella* by Schuchert and Cooper should be placed in *Onniella* Bancroft, regarded by Schuchert and Cooper as a probable synonym of *Dalmanella*. Cooper (1942, p. 229) did not altogether agree with this and stated that most of the species are congeneric with *Resserella* Bancroft, but subsequently (1944) regarded *Onniella* as a subgenus of *Resserella*. More recently Cooper (1956, p. 956) noted that the specimen chosen by Schuchert and Cooper as lectotype of *Orthis canalis* Sowerby 1839, type species of *Resserella* Bancroft, is congeneric with *Parmorthis* Schuchert and Cooper, and so proposed the new genus *Paucicrura* to embrace those species he had formerly placed

in *Resserella*. Thus *Onniella* Bancroft and *Paucicrura* Cooper should replace *Dalmanella* Hall and Clarke of Schuchert and Cooper and *Resserella* Bancroft of Cooper; *Resserella* Bancroft replaces *Parmorthis* Schuchert and Cooper; *Dalmanella* Hall and Clarke replaces *Wattsella* Bancroft. It seems likely that *Paucicrura* Cooper is a synonym of *Onniella* Bancroft.

The genus *Onniella* Bancroft has been interpreted rather broadly to include *O.* (?) *tyersensis*. Externally and in the internal features of the ventral valve it is closely comparable to such species as the Upper Silurian '*Dalmanella*' *crassiformis* Kozłowski 1929 (p. 67, Pl. 1, fig. 30-1), but from this and similar species it differs in the long-shafted cardinal process, the comparatively heavy socket ridges and the wide separation of the dorsal muscle fields. *Onniella distincta* Poulsen (1934, p. 14, Pl. 1, fig. 12-15), from the Silurian of Greenland, is a species which also possesses this last feature. Forms closely related to *O.* (?) *tyersensis* are known to occur in the Melbourne Beds.

Genus *Tyersella* gen. nov.

DIAGNOSIS: Large, biconvex, multicostellate onniellids with low interareas, thick pedicle callist, heavy triangular teeth supported by strong advancing dental lamellae continued anteriorly as a muscle bounding ridge of the elongate schizophorid ventral muscle field. Dorsal interior with strong diverging inner socket ridges, small bilobed cardinal process and with large anterior adductors separated from the small posterior adductors by a transverse ridge. Ventral pallial sinuses digitate, closely comparable to those of *Levenea*.

TYPE SPECIES: *Tyersella typica* sp. nov.

RELATIONS: The features of the dorsal valve of *Tyersella* are extremely close to those of the North American and European Silurian and Devonian genus *Levenea*. The only noticeable difference is the marked inequality in the size of the anterior and posterior adductors in *Tyersella*. The close relationship can be seen particularly in the pattern of the dorsal pallial sinuses, for those of *Tyersella* are exactly identical with those of *Levenea* as shown by Schuchert and Cooper (1932, p. 40, Fig. 14). The two genera are obviously distinct in the ventral musculature which in *Tyersella* is elongate with a strong median ridge and is typically schizophorid in character, whereas that of *Levenea* is short and pentagonal in outline. *Levenea* also has obsolete dental lamellae in adult growth stages, whereas in *Tyersella* they are strongly developed in all growth stages. Because of emphasis placed by Schuchert and Cooper on the presence or absence of fulcral plates in the classification of dalmanellacids, *Tyersella* must be placed with other such genera which lack fulcral plates in the Onniellidae. However Bancroft (1945, p. 187) has questioned the use of this feature for classification at the family level. Bancroft writes 'The presence of fulcral plates in immature individuals of certain Dalmanellidae detracts greatly from the merits of this classification, and it is further impaired by the fact that those structures persist in certain individuals of species which have normally the *Dalmanella* type of crural plate. Even on an artificial basis the classification is, therefore, unsatisfactory.' Should fulcral plates be disallowed as a feature of prime classificatory value, then *Tyersella* would find its place in the Schizophoriidae, along with such genera as *Schizophoria*, *Isorthis* and perhaps *Levenea* on the basis of surface ornament, musculature, general features of the cardinalia and more especially the similarity in the dorsal pallial sinuses, particularly with those of the last two genera.

Tyersella typica sp. nov.

(Pl. XXX, fig. 12-19; Fig. 10)

DESCRIPTION:

EXTERIOR—Large, subequally biconvex onniellids with short hinge line, rounded outline and anterior commissure, and with greatest width about midlength of the shell. Ventral interarea comparatively low and convex with umbo slightly incurved, apsacline and with delthyrium narrow and open; dorsal interarea extremely low and plane, anacline or orthocline, and with open notothyrium the margins of which curve outwards from the umbo so that it is not clearly delineated within the interarea.

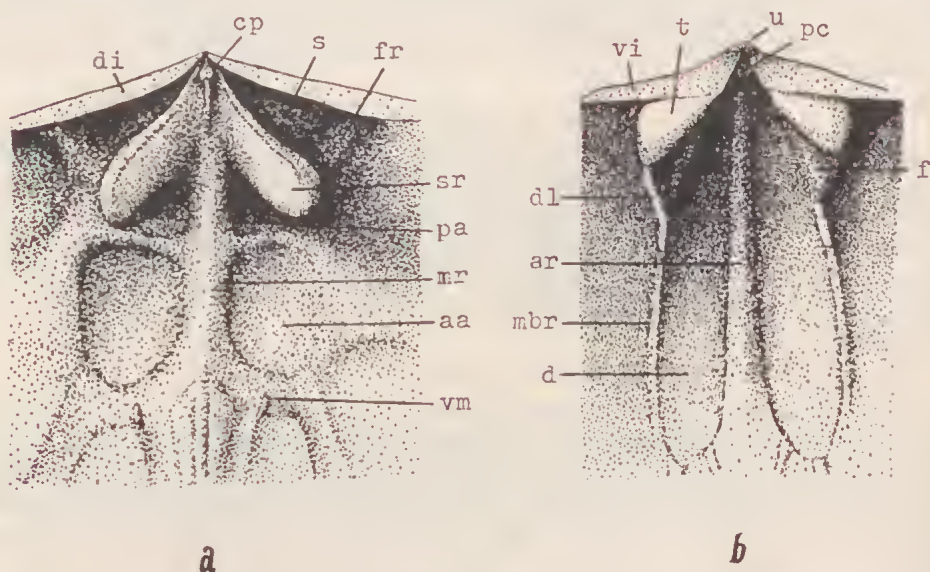


FIG. 10—*Tyersella typica* gen. et sp. nov. (a) Dorsal interior based on latex impression of holotype M.3426; (b) Ventral interior based on latex impression of M.3428. cp: cardinal process, di: dorsal interarea, s: socket, sr: socket ridge, fr: fulcral ridge, aa: anterior adductor impression, pa: posterior adductor impression, mr: median ridge, vm: vascula media, ar: adductor ridge, d: diductor scar, dl: dental lamella, f: 'socket ridge' fossette, mbr: muscle bounding ridge, pc: pedicle callist, t: tooth, u: umbo, vi: ventral interarea. x 5 approx.

Surface ornament parvicostellate with each valve bearing about 140 fine costellae spaced 4 per mm around the anterior commissure.

VENTRAL INTERIOR—Delthyrial cavity deep and narrow, laterally outlined by the strong advancing dental lamellae which are continued anteriorly as a high muscle bounding ridge. Posteriorly the delthyrial cavity is shallowed by a large triangular pedicle callist (= pedicle collar?) at the apex of the valve showing transverse muscle markings. Teeth strong and triangular with deep 'socket ridge' fossettes immediately beneath the teeth at the anterior end of the dental plates. Ventral muscle area elongate, posteriorly bounded by the pedicle callist and extending anteriorly from between one-half and one-third of the distance to the anterior margin, and consisting of two narrow slightly expanding diductor furrows separated by a high

narrow adductor ridge which shallows posteriorly. Ventral pallial sinus obscure, but apparently digitate.

DORSAL INTERIOR—Diverging inner socket ridges extremely high and heavy, occasionally bearing a slight longitudinal furrow along their upper edges (dorsal adjustor scars?), and anteriorly bounding large sockets. Cardinal process small, with a short shaft and a usually bilobed myophore and often with a posterior continuation of the shaft past the myophore to the umbo. Dorsal muscle bounding ridges arising from the base of the socket ridges, outlining the adductor field which extends about half-way to the anterior margin. Adductors medianly divided by a low ridge, caused mainly by the incision of the muscle areas into the floor of the valve. Posterior adductors small, triangular, almost hidden by the overhanging socket ridges, and separated from the larger, more rounded anterior adductors by a transverse ridge arising just anterior to the base of the socket ridges and extending slightly backwards across the muscle area to meet the median ridge. Dorsal pallial sinuses digitate with the vascula media arising from just anterior of the muscle field and immediately bifurcating into a median trunk which is continued to the anterior margin with a slight tendency to bifurcate again near the margin, and a lateral trunk which extends from the anteriolateral margin of the adductor at about 45° to the midlength of the shell and bifurcates half-way to the margin. The vascula myaria arise from the junction of the anterior and posterior adductors and extend laterally to bifurcate half-way to the margin of the shell.

GERONTIC FEATURES: The abundant material from Tyers illustrates a number of changes which take place during the ontogeny of this species. Apart from such usual features as the deposition of secondary material thickening the socket ridges and dental lamellae, and the general incision of muscle areas and pallial sinus, one finds that the sockets become secondarily outlined by low fulcral ridges (Pl. XXX, fig. 14), there is also the development of a weakly papillose genital area on each side of the ventral muscle area (Pl. XXX, fig. 18), there may be secondary deposition of shell material along the paths of the vascula myaria valve in the dorsal so that they appear as ridges (Pl. XXX, fig. 13), and a median ridge in the dorsal valve anterior to the muscle field and separating the vascula media may be developed (Pl. XXX, fig. 13-14).

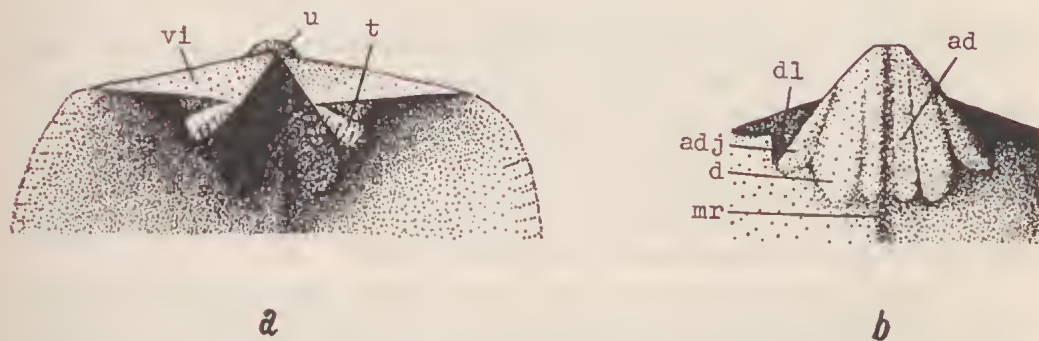


FIG. 11—*Resserella impensa* sp. nov. (a) Ventral interior drawn from latex impression of M.3431; (b) Internal mould of ventral valve M.3431. ad: adductor impression, adj.: adjustor impression, d: diductor impression, dl: dental lamella, mr: median ridge, t: tooth, u: umbo, vi: ventral interarea. $\times 5$ approx.

MEASUREMENTS: M.3426, l. = 21 mm, w. = 20 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3426 A, B (dorsal valve); M.3425, 7-9, all from Loc. 36, Conglomerate Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 2 (rare), 11 (occasional), 18 (rare), Limestone Phase; Loc. 29 (rare), 30 (occasional), 31 (rare), 34 (rare), 35 (?), 36 (abundant), Conglomerate Phase; 47 (rare), 49 (rare), Boola Beds.

REMARKS: The material from the limestone is extremely fragmentary, so that the identifications are based on external features alone. A further undescribed species of *Tyersella* has been collected from the Kinglake district.

Family DALMANELLIDAE Öpik

Genus *Resserella* Bancroft 1928

(= *Parmorthis* Schuchert and Cooper 1931)

Resserella impensa sp. nov.

(Pl. XXX, fig. 20-4; Fig. 11)

DIAGNOSIS: Large *Resserella* with comparatively coarse fascicostellate ornament, widely separated socket ridges and upright cardinal process.

DESCRIPTION:

EXTERIOR—Outline rounded with greatest width just anterior to the comparatively long hinge line; cardinal extremities rounded. Shell plano-convex with ventral valve strongly convex and arched. A faint sulcus may be present in the dorsal valve, but this fades anteriorly so that the anterior commissure is rounded. Ventral interarea high and strongly convex with the ventral umbo strongly incurved over the hinge line. Ventral interarea apsacline and dorsal interarea anacline. Both delthyrium and notothyrium wide and open, although notothyrium tends to be closed by the cardinal process.

Surface of both valves fascicostellate with each valve bearing about 80 costellae which marginally are spaced at about 3 or 4 per mm. A zone of fine costellae is sometimes present medianly in immature specimens.

VENTRAL INTERIOR—Delthyrial cavity deep and bounded laterally by heavy dental lamellae the base of which is projected anteriorly as low muscle bounding ridges. A small triangular pedicle callist is present at the apex of the ventral valve. The teeth are strong and triangular with heavy crenulations along their inner surfaces. Ventral muscle area confined to the delthyrial cavity, triangular in shape and consisting of flabellate diductor scars situated each side of lanceolate adductor impressions which are separated by a low median ridge. Adjustors represented as large triangular scars lateral and somewhat posterior to the diductors and extending up the sides of the dental lamellae. Deep 'socket ridge fossettes' are developed beneath the teeth at the anterior end of the dental plates.

DORSAL INTERIOR—Sockets deep and crenulate, laterally bounded by low fulcral plates and anteriorly delimited by the heavy, widely separated, divergent, inner socket ridges. Cardinal process with short shaft only extending a short distance down the median ridge, directed more ventrally, giving rise to an upright cardinal process bearing a bilobed myophore which tends to close the notothyrium. Dorsal muscle area elongate and narrowing anteriorly, extending about half-way to the anterior margin. Adductors separated by a narrow median ridge which stops

abruptly at the anterior end of the muscle area. Anterior adductors much smaller than posterior adductors and separated by an ill-defined ridge which extends slightly backwards across the muscle area.

MEASUREMENTS: M.3430, l. = 11 mm, w. = 12 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3430, Loc. 48, Boola Beds; M.3431-2, Loc. 36, Conglomerate Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 40 (rare), 48 (occasional), Boola Beds; Loc. 34 (rare), 36 (common), Conglomerate Phase, Coopers Creek Formation.

REMARKS: The ventral musculature, the strongly crenulate teeth, the upright cardinal process and the elongate dorsal muscle area with the small anterior adductors show this form to be a species of the Silurian genus *Resserella*. The coarse ornament, tending to be fascicostellate, separates the species from the North American and European representatives of the genus. The ornament, however, is not so coarse as that of *Resserella crassicostata* (Schuchert and Cooper 1932, Pl. 21, fig. 4-5). The upright cardinal process is a feature seen in other species of *Resserella* and is most strongly developed in *R. visbyensis* (Lindström). It is a character probably related to the leverage required to open the valves in forms with flat dorsal valves and strongly arched ventral valves.

The genus *Resserella* has previously been described from Australia twice (as *Parmorthis*) but both these identifications may be questioned. *Parmorthis vandiemeni* Gill (1948, p. 65, Pl. 8, fig. 30) from the Lyell Highway, Tasmania, does not appear to possess the dorsal musculature of *Resserella*. No description of the ventral valve is given and the description and figure of the dorsal valve are such that even the correct family relationships of the species are obscure. The general pattern of the dorsal interior however appears to be unlike that of any of the Tyers dalmanellacids. Gill (1950) recorded the genus again from Tasmania, but again the generic identification of the specimen concerned is far from clear (see p. 203). Much of the literature on the Silurian and Devonian stratigraphy and palaeontology of Victoria contains references to the occurrence of '*Orthis elegantula* Dalman' or '*Dalmanella elegantula* (Dalman)' but this identification appears to have been applied indiscriminately to any dalmanellacid.

Family SCHIZOPHORIIDAE Schuchert

Genus *Isorthis* Kozłowski 1929

Isorthis festiva sp. nov.

(Pl. XXXI, fig. 3-6; Fig. 12)

DIAGNOSIS: *Isorthis* with comparatively strong dental lamellae, bladed inner socket ridges and large dorsal muscle area.

DESCRIPTION:

EXTERIOR—Outline rounded, with greatest width slightly posterior to the midlength of the shell. Hinge line short, with rounded cardinal extremities. Shell unequally biconvex, with ventral valve more strongly arched than dorsal valve. A low sulcus, extending to the broadly sulcate anterior commissure, is present in the dorsal valve. Ventral interarea plane, higher than dorsal interarea, apsacline. Dorsal interarea plane and anacline. Delthyrium and notothyrium both open.

Surface of both valves multicostellate, with each bearing about 110 costellae which marginally are spaced at about 4 per mm.

VENTRAL INTERIOR—Delthyrial cavity fairly deep and bounded laterally by comparatively strong dental lamellae which support triangular teeth. The dental lamellae are continued anteriorly for a short distance as low muscle bounding ridges. Ventral muscle area elongate, extending about one-third the distance to the anterior commissure, and consisting essentially of two narrow, expanding diductor scars set on each side of a narrow adductor ridge. Obscure adjustor scars present laterally to the diductor impressions at the base of the dental lamellae.

DORSAL INTERIOR—Sockets deep, laterally bounded by low fulcral plates and anteriorly delineated by the comparatively thin and bladed inner socket ridges. Cardinal process with fairly long shaft and usually bilobed myophore tending to close the notothyrium. Dorsal muscle area subquadrate, usually extending more than half-way to the anterior margin, with a wide median ridge. Posterior and anterior adductors subequal, separated by a low transverse ridge.

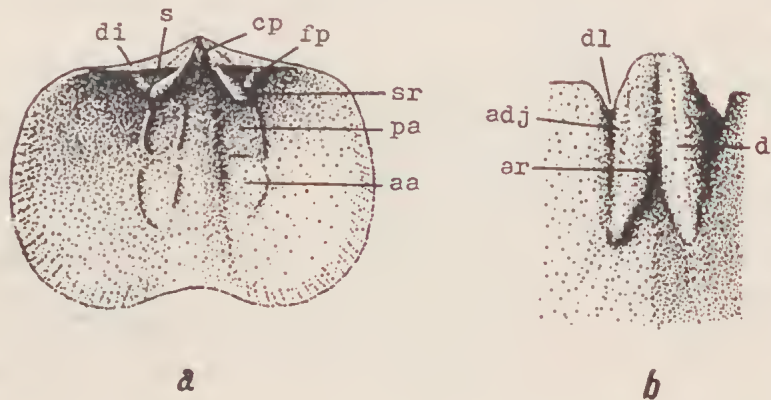


FIG. 12—*Isorthis festiva* sp. nov. (a) Dorsal interior based on a latex impression of M.3437; (b) Internal mould of dorsal valve of holotype M.3436. aa: anterior adductor impression, pa: posterior adductor impression, cp: cardinal process, di: dorsal interarea, fp: fulcral plate, s: socket, sr: socket ridge, adj: adjustor muscle impression, ar: adductor ridge, d: diductor muscle impression, dl: dental lamella. x 5 approx.

MEASUREMENTS: M.3436, l. = 13 mm, w. = 13 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3436, A-B, Loc. 47; M.3435, 7, Loc. 49, Boola Beds.

OCCURRENCE: Loc. 47 (occasional), 48 (rare), 49 (occasional), Boola Beds.

REMARKS: As far as can be judged from the existing material this species is a typical member of the Silurian and Devonian genus *Isorthis*. The ventral interior, however, is known only from one fragmentary specimen.

Schizophoria allani Shirley 1938 (p. 465-6, Pl. 41, fig. 1-3), from the Lower Devonian Baton R. Beds of New Zealand, undoubtedly represents another Austra-

lasian species of *Isorthis*, although Gill (1950), in identifying Shirley's species from the Bell Shale, Tasmania, referred it to the genus *Parmorthis* Schuchert and Cooper (= *Resserella* Bancroft). However Shirley's description and figures make it clear that the species is a schizophorid, and, on the basis of the dorsal musculature and cardinalia, a species of *Isorthis*. Whether or not the internal mould figured by Gill (Pl. 1, fig. 24) belongs to the genus *Isorthis* remains to be demonstrated; fulcral plates appear to be present in the specimen, but no figure or description is given of the ventral interior. Gill (1949) had previously described a further Australasian species of *Isorthis* from the Lower Devonian of Sandy's Cr., Gippsland, but this time in the Upper Devonian genus *Cariniferella* Schuchert and Cooper. Gill's figures show the form to be a schizophorid, and, as far as can be assessed without reference to type material, a typical species of *Isorthis*. In fact, from the somewhat sheared rocks of Sandy's Cr., Gill recognized two species—*Cariniferella alpha*, a narrow form, and *Cariniferella beta*, a wide form. These two 'species' are obviously based on secondary shape changes of the one form caused by deformation of the enclosing matrix. Thus, in a sense, it is fortunate that *C. beta* Gill is preoccupied by *C. beta* (Williams 1908), leaving but the one name for the Sandy's Cr. form. Similar shape variations can be seen in the figured specimens of *Isorthis allani* (Shirley 1938, cf. Pl. 41, fig. 1-2) and even in the Tyers dalmanellacids (e.g. *Resserella impensa*, Pl. 30, fig. 23-4).

Isorthis festiva differs from the other Australasian species most obviously in its larger dorsal muscle field. From the North American and European species it differs in the generally more bladed socket ridges and better developed dental lamellae, and the less well defined ventral adductor ridge.

Genus *Schizophoria* King 1850

Schizophoria sp. indet.

(Pl. XXXI, fig. 1-2)

DESCRIPTION: Dorsal valve strongly convex, with long straight hinge line, moderately high orthocline interarea, open notothyrium, and rounded anterior commissure.

Cardinalia large with inner socket ridges bladed and strongly divergent, supported by vertical plates and continued as high muscle bounding ridges. Cardinal process represented by a short ridge, perhaps with lower subsidiary ridges. Muscle area large, extending over half-way to the anterior commissure, with diductors separated by a low broad median ridge, not clearly differentiated into anterior and posterior scars. Sockets small and shallow, defined by low fulcral plates.

Surface of shell marked by multicostellate ornament.

MEASUREMENTS: M.3433, l. = 20 mm, w. = 18 mm.

FIGURED SPECIMENS AND OCCURRENCE: M.3433, Loc. 47, Boola Beds; M.3434, Loc. 49, Boola Beds, may also belong to this species.

REMARKS: One single fragmentary internal mould of a dorsal valve of this species is present in the collection. An even more incomplete ventral interior from Loc. 49 may belong to the same species (Pl. XXXI, fig. 2). This shows a schizophorid muscle impression in which the median adductor ridge is wider and more sharply defined than that of either *Tyersella typica* or *Isorthis festiva*. The dental lamellae also appear to be less strongly developed than in those species. The material does not permit positive identification of the species.

Superfamily PENTAMERACEA Schuchert

Family PENTAMERIDAE McCoy

Genus *Gypidula* Hall 1867'*Gypidula*' *victoriae* Chapman

(Pl. XXXI, fig. 7-8)

Gypidula victoriae Chapman 1913, p. 106-7, Pl. 11, fig. 12.

DESCRIPTION:

EXTERIOR—Outline longitudinally elliptical, with highly convex ventral valve. Hinge line short with maximum width of shell about midlength. Anterior commissure broadly crenulate, due to a ventral fold which bears a shallow sulcus on the anterior half of the valve. Umbo incurved over the low apsacline interarea. Delthyrium open. Surface with faint growth lines.

VENTRAL INTERIOR—Delthyrial cavity deep, teeth apparently blunt, dental lamellae posteriorly united into a short spondylium supported by a stout median septum which extends about one-quarter the distance to the anterior margin.

MEASUREMENTS: l. = 8 mm, w. = 5 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3438 A-B, Loc. 43, Boola Beds.

REMARKS: The single ventral valve from Tyers is undoubtedly conspecific with Chapman's species from Ruddock's Quarry, known from an incomplete internal mould of both valves. Although the ventral interior suggests the species is correctly assigned to *Gypidula*, positive identification is not possible till the dorsal interior is properly known.

Superfamily PLECTAMBONACEA Williams

Family LEPTESTIIDAE Williams

Genus *Plectodonta* Kozłowski 1929*Plectodonta bipartita* (Chapman)

(Pl. XXXI, fig. 18-19)

Chonetes bipartita Chapman 1913, p. 104-5, Pl. 10, fig. 8-10.

Stropheodonta bipartita (Chapman) Gill 1942, p. 41, Pl. 5, fig. 7-9, Pl. 6, fig. 10.

Plectodonta bipartita (Chapman) Gill 1948b, p. 13; Gill 1950, p. 249, Pl. 1, fig. 21-3.

non *Leptaena bipartita* Hall 1852, p. 326, Pl. 74, fig. 4-5.

= *Stropheodonta bipartita* (Hall) auct. = *Leptostrophia bipartita* (Hall).

DESCRIPTION:

EXTERIOR—Small, semicircular shells with rounded outline and strongly concavo-convex profile. Hinge line long and straight, marking the greatest width of the shell; cardinal extremities angular. Anterior commissure rounded. Ventral interarea low and long, apsacline, with a triangular delthyrium apparently closed apically by a small pseudodeltidium. Dorsal interarea extremely low, hypercline, with the notothyrium closed by a tripartite structure probably representing a pair of chilidial plates ankylosed to the median cardinal process.

Surface ornament parvicostellate, with each valve bearing from about 14 to 20 coarser costellae between which marginally there may be as many as 7 finer costellae. These are crossed by irregularly spaced growth lines.

VENTRAL INTERIOR—Ventral valve with a small ventral process probably buttressing the pseudodeltidium at the posterior of the deep delthyrial cavity. Diductor scars ovate, widely diverging at an angle of about 45° , deeply impressed, and arising just anterior to the ventral process and extending about half-way to the anterior commissure. Adductors probably located in the angle between the divergent diductor scars and just anterior to their median junction. Inner surface papillose with the papillae strongly developed and radially aligned in a zone about 1 mm wide around the commissure. In this zone the stronger costellae of the exterior are represented as radial grooves. Hinge line denticulate over half-way to the cardinal extremities with about 10 denticles per mm.

DORSAL INTERIOR—Dorsal valves with a strong, probably trilobed structure filling the notothyrium (= chilidial plates + cardinal process?). Arising immediately anterior to this process is a narrow median furrow which extends most of the distance to the anterior commissure and shallows anteriorly. Inner socket ridges short but well developed, arising from each side of the fused dorsal process, strongly divergent, almost parallel to the hinge line. 4 septa present with the inner pair much more strongly developed than the outer pair. The high inner pair arise just anterior to the cardinalia, diverge at an angle of about 20° , and extend about three-quarters of the distance to the anterior margin. Outer pair arising well anterior to the cardinalia, close and almost parallel to the inner pair, but only about half their length. Curved 'lophophore platform' surrounding the septa variably developed and seen only on occasional specimens. Inner surface more strongly papillose than that of the ventral interior and with a similar marginal zone of smaller radially aligned papillae. Hinge line bearing sockets (?) for the ventral hinge denticles.

MEASUREMENTS: M.3447, l. = 4 mm, w. = 6 mm.

FIGURED SPECIMENS: M.3446-7, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 25, Mudstone Phase, Coopers Creek Formation (?); Loc. 39 (rare), 40 (occasional), 41 (rare), 42 (rare), 43 (abundant), 44 (occasional), 45 (rare), 46 (rare), 47 (rare), 52 (occasional), 53 (rare), 54 (rare), Boola Beds.

REMARKS: Although Gill (1942), in wrongly assigning this species to the Devonian genus *Stropheodonta* Hall, made Chapman's trivial name a type of secondary homonym of *Stropheodonta* (*Leptostrophia*) *bipartita* (Hall), this does not require correction as, previously, Caster (1939) had established Hall's subgenus as a genus within its own right. Gill (*op. cit.*) gives this species as one of his zone fossils of the Yeringian which, he considered, indicate a Devonian age for the series. However, the genus *Plectodonta* is more typical of Silurian rocks elsewhere in the world.

Apart from differences in surface ornament *P. bipartita* differs from *P. mariae* Kozłowski, the type species of the genus, in the more posterior location of the ventral diductor impressions. This feature it shares with certain British Silurian species such as *Plectodonta millinensis* cf. var. *canastonensis* Jones (Lamont and Gilbert 1945, p. 659, Pl. 4, fig. 13-19). *P. bipartita* resembles most closely *P. davidi* (Mitchell) (Brown 1949, p. 199, Pl. 14, fig. 1-6) from the Silurian of Yass, N.S.W., particularly in the internal features of the ventral valve. *P. davidi*, however, apparently lacks the strong median furrow present in the dorsal valve which is so characteristic of *P. bipartita*. The species is widely distributed through the Boola Beds with its common associate *Lissatrypa lenticulata* sp. nov.

Genus *Notanoplia* Gill 1950

Notanoplia Gill 1950, p. 249 *et seq.*

Gill (1950) proposed this genus to include a new species, *N. pherista*, from the Bell Shale, Tasmania, as well as two species previously described by him (1942) from the Yering Beds in the North American genus *Anoplia* (viz. *A. australis* and *A. withersi*). A further species, *N. loyolensis* Gill, from the Loyola district, has subsequently been described (Gill 1951b). Gill considered his genus to be very closely related to the North American chonetid *Anoplia*, so much so, that he regarded the genera as isochronous on the basis of their similarity (Gill 1950, p. 250). A review of the characters of the genus given below suggests that the genus represents a brachiopod with leptestiid affinities rather than a chonetid, and so the stratigraphic and palaeogeographic arguments based on the occurrence of the species of the genus may be discounted.

REVIEW OF THE FEATURES OF *Notanoplia* GILL:

EXTERNAL FEATURES—The species referred to the genus are all small, semi-circular, plano-convex or slightly concavo-convex, comparatively smooth brachiopods. *N. australis* and *N. withersi* are described as smooth forms (Gill 1942) whilst *N. pherista* is 'smooth except for traces of radial costellae' sometimes crossed by concentric growth lines (Gill 1950, p. 251). This type of ornament is well developed in *Notanoplia* sp. described below (Pl. XXXI, fig. 16). There is a complete absence of spine bases and spines along the ventral interarea in *Notanoplia*. Cardinal spines are present in *Anoplia helderbergiae* but are usually considered to be absent in *A. nucleata* (Hall), the type species of *Anoplia* Hall and Clarke. It may be noted, however, that Hall and Clarke (1892, p. 293) state of this species. 'No external evidence of cardinal spines, though spine tubes exist in one or more pairs in the substance of the pedicle valve'. No comparable structures are present in any species of the genus *Notanoplia*. The shell material is as yet unknown in all species of *Notanoplia*.

SEPTATION—The most striking feature in all species referred to the genus is the development of strong, blunt, almost platformed septa in each valve. In general, in the ventral valve there is a strong median septum, with two well developed secondary septa bisecting the angles between the median septum and the hinge line. In *N. withersi* there are two further subsidiary septa between the median septum and the secondary septa, while in *N. loyolensis* another pair of secondary septa is described. The most remarkable feature of this excess of septation is that each septum of the ventral valve has a corresponding septum in the dorsal valve in those species in which the dorsal interior is known. Although septa subsidiary to the median septum may be present in species of *Chonetes* they are always comparatively weakly developed and corresponding septa are not present in the opposing valve. The excess of strong septa is more characteristic of plectambonacids as a whole, and indeed similar septation is present in species of *Sowerbyella* although the dorsal median septum is typically absent (Jones 1928). The nature of the septa is of interest also. In *Chonetes* they are generally low and sharp, whereas in *Notanoplia* the septa, particularly the median septum, are high and platformed, suggesting that perhaps they were the seat of muscle attachment. The muscle impressions are unknown in all species.

CARDINALIA—In the nature of the cardinalia the relationships of *Notanoplia* are clearest. In the Tyers specimens of *Notanoplia* sp. (described below) this consists

of strong, divergent socket ridges anchylosed to what probably represents a combined cardinal process and chilidial plates. The components of this 'dorsal process' are not well defined in the Tyers specimens of *Notanoplia* sp. but one specimen suggests it is trilobed (Fig. 13b). Furthermore, Gill (1950) described the dorsal interior as possessing a 'trilobed cardinal process' in *N. pherista*. This type of cardinalia is completely foreign to chonetids but it is typical of the plectambonacid family Leptestiidae Williams and more particularly the subfamily Sowerbyellinae Öpik (*vide* Williams 1953b).

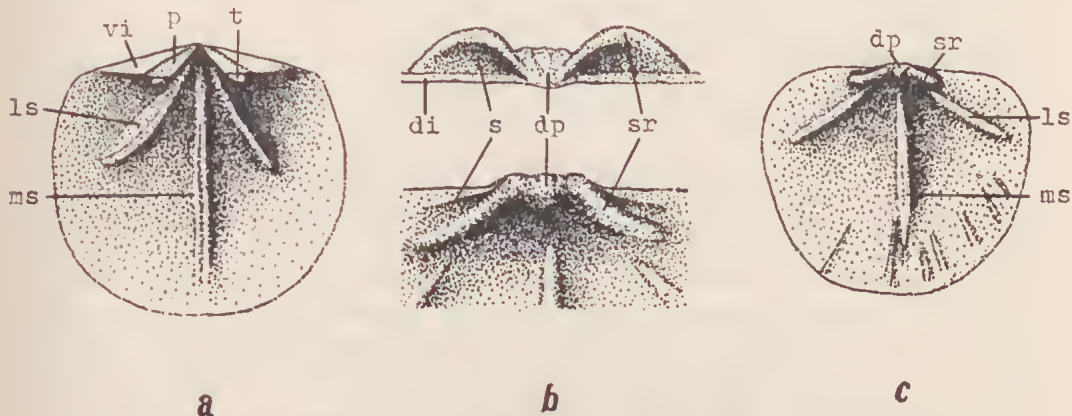


FIG. 13—*Notanoplia* spp. (a) *Notanoplia australis* (Gill). Ventral interior based on a latex impression of M.3439; x 5 approx. (b) *Notanoplia* sp. Posterior and ventral aspects of the cardinalia, based on a latex impression of M.3442; x 10 approx. (c) *Notanoplia* sp. Dorsal interior, based on a latex impression of M.3443; x 5 approx. ls: lateral septum, ms: median septum, p: perideltidium, t: tooth, vi: ventral interarea, di: dorsal interarea, dp: dorsal process, s: socket, sr: socket ridge. x 5 approx.

Thus it is considered that, rather than a chonetid closely related to *Anoplia*, *Notanoplia* represents an indigenous genus of leptestiid brachiopod. This conclusion must in a sense be regarded as provisional as the only dorsal interiors examined were of *Notanoplia* sp. from the Boola Beds. Material of the other species, in particular the type species *N. pherista* Gill, was not available for study.

Notanoplia australis (Gill)

(Pl. XXXI, fig. 9-10; Fig. 13a)

Anoplia australis Gill 1942, p. 38, Pl. 4, fig. 8; Gill 1945, p. 144.

Notanoplia australis (Gill) Gill 1951b, p. 64.

DESCRIPTION:

EXTERIOR—Ventral valve small, semicircular to subquadrate with rounded outlines and strongly convex profile. Greatest width slightly anterior of the long straight hinge line; cardinal extremities angular and anterior commissure rounded. Interarea comparatively high and apsacline, with the umbo strongly incurved, and with a widely triangular delthyrium which is apparently open. Outside the delthyrium is a perideltidium separated from the rest of the interarea by a perideltidial

line which runs from the umbo to meet the hinge line slightly less than half-way to the cardinal extremities. Ornamentation of the interarea obscure. Surface smooth.

VENTRAL INTERIOR—Delthyrial cavity deep, with 3 strong septa arising from near the apex of the valve. The median septum extends almost to the anterior commissure and is high and blunt and bears a groove toward its anterior end. The high lateral septa diverge at an angle of about 45° to the median septum and extend about half-way to the margin. Two moderately large triangular teeth are mounted each side of the delthyrium. Muscle impressions not visible on the smooth inner surface of the shell.

Dorsal valve not present in the Tyers material.

MEASUREMENTS: M.3439, l. = 5 mm, w. = 5 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3439, Loc. 47, Boola Beds (rarc).

REMARKS: The fragmentary specimens from the Boola Beds were found difficult to classify in terms of the existing species of *Notanoplia* as at present defined. Two species appear to be represented in the collection. The first, a comparatively small, smooth form, represented by a few, mostly fragmentary ventral valves, is apparently very close to the Yeringian species *N. australis* (Gill). The second, a larger form, approaches more closely *N. pherista* Gill from the Bell Shale, in that it possesses a surface ornament of subdued radial costellae crossed by concentric growth lines. Besides this it differs from *N. australis* in possessing a flatter ventral valve, lower, more divergent lateral septa in each valve and a marginal zone of well developed radial ridges on the insides of the valves. Most of these differences could conceivably have arisen from the secondary deformation and compaction of individuals of a single, variable species, particularly in view of the wide gradation there exists in these features. However, in view of the presence of surface ornament in the second form, it seems most likely that two species are present. *N. loyolensis* Gill 1951 (p. 53, fig. 1-4), based on a single ventral interior from Loyola, and probably from a similar horizon to that of the Boola Beds, is characterized by the possession of 7 septa. Some of these could represent the strongly developed internal radial ridges which are normally confined to the shell margins in the second form from Tyers described as *Notanoplia* sp. below. This form cannot be identified more positively, nor safely described as a new species till *N. loyolensis* is properly known and the other species of *Notanoplia* better defined.

Notanoplia sp.

(Pl. XXXI, fig. 11-17; Fig. 13b-c)

DESCRIPTION:

EXTERIOR—Comparatively large *Notanoplia* with rounded to subquadrate outline and rounded anterior commissure, and with greatest width about midlength of the shell. Profile plano-convex, with the ventral valve gently convex. Hinge line long and straight with the cardinal extremities angular. Ventral interarea comparatively high and apsacline with umbo incurved over the hinge line and with an apparently open delthyrium. Dorsal interarea extremely low and hypercline with a small notothyrium closed by the 'dorsal process'.

Surface ornament of subdued well-spaced radial costellae crossed by irregularly spaced growth lines giving a reticulate appearance to the shell surface. About 50 costellae on each valve.

VENTRAL INTERIOR—Delthyrial cavity comparatively deep with three strong septa arising from near the apex of the valve. The wide blunt median septum extends almost to the anterior commissure and bears a well developed groove toward its anterior end. The lateral septa are much lower than the median septum and diverge at an angle of about 60° to the median septum. They extend about half-way to the margin. Two strong teeth are mounted on each side of the delthyrium. Inner surface of shell usually marked by a marginal zone of radial ridges.

DORSAL INTERIOR—Notothyrial cavity extremely shallow with short strong widely divergent socket ridges anchylosed posteriorly to a 'dorsal process' at the apex of the valve which probably consists of a pair of chilidial plates and a short-shafted cardinal process. Sockets shallow, poorly defined apart from the socket ridges. A high blunt median septum extends from immediately anterior of the cardinal process almost to the anterior commissure. Lateral septa similar to those of the ventral valve. Interior of the valve smooth or with occasional radial ridges toward the margins.

MEASUREMENTS: M.3444, l. = 6 mm, w. = 6.5 mm.

FIGURED SPECIMENS: M.3440, Loc. 36, Conglomerate Phase, Coopers Creek Formation; M.3441-5, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 36 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 40 (rare), 43 (abundant), 45 (rare), Boola Beds.

Superfamily STROPHOMENACEA Schuchert

Family STROPHOMENIDAE King

Genus *Notoleptaena* Gill 1951

Notoleptaena Gill 1950, p. 253 (nomen nudum).

Notoleptaena Gill 1951a, p. 191 *et seq.*

? *Rugoleptaena* Havlíček 1956, p. 558-61.

Gill (1951a) proposed this genus to include two new species from the Lower Devonian of Victoria, although the name was employed in an earlier paper which inadvertently predated the generic description. Although this does not effect the genus *Notoleptaena*, in the same paper Gill (1950) a new species of *Notoconchidium*, *N. florenceusis*, was described and *Pentamerus tasmaniensis* Etheridge 1883 was referred to that genus. As this publication predates what was intended to be the original generic description, then the genus dates from 1950, and the choice of type species must lie between the two abovementioned species.

The genus *Notoleptaena* is to be distinguished from *Leptaena* in the configuration of the valves. Instead of the dorsally deflected trail of *Leptaena* the genus is described as possessing a ventrally deflected dorsal margin and a dorsally deflected ventral tongue. Furthermore, the dorsal valve is described as convex with an anterior gap for the reception of the ventral tongue. These features are seen in *N. linguifera*, the type species of the genus, but in the other Victorian species, *N. otophera*, the shape of the dorsal valve is as yet unknown. A similar configuration of the valves is seen in *Leptaena bouei* Barrande from Bohemia, Europe and Russia.

Havlíček (1956) has proposed a very similar genus *Rugoleptaena* which differs solely from *N. linguifera* in that the dorsal valve possess a dorsally deflected anterior margin. The species which Havlíček includes in his genus are *Rugoleptaena hornyi* Havlíček and *Leptaena emarginata* (Barrande). The actual configuration of the valves in these strophomenoids appears to be so variable (as with other strophomenoid groups) that probably the best procedure would be to regard the

abovementioned species as congeneric till such times as they are better known. The forms appear to constitute a fairly close knit group, for crenulate teeth have been reported in *Leptaena emarginata* (Barrande) (Kozłowski 1929) with 'rugoleptaenid' valves, and in *N. otophera* Gill with apparently 'notoleptaenid' valves. It is unfortunate that the type species of *Notoleptaena* comes from the comparatively coarse sandstones of the Heathcote district so that the internal features are difficult to interpret. A precursor to the group is probably seen in such Silurian emarginate species as *Leptaena bella* Williams from the Llandovery of Wales.

Gill (1951a) in his discussion of the palaeo-ecology of *Notoleptaena* considered that the forms concerned were without a functional pedicle (as he did also of *Leptaena*, contra Williams 1953b). Although it appears that in *Leptaena emarginata* the pedicle probably atrophied during ontogeny, the specimens of *N. otophera* from the Boola Beds (preserved as moulds) show a thread of matrix extending from the ventral umbonal cavity to the enclosing matrix. This suggests that a functional pedicle was present at least in this species.

Notoleptaena otophera Gill

(Pl. XXXIII, fig. 12-13)

Notoleptaena otophera Gill 1951a, p. 200-3, Pl. 1, fig. 24-7.

DESCRIPTION:

EXTERIOR—Ventral valve slightly convex in the umbonal region, becoming planate and then with a strong sharp dorsal geniculation which is deepest along the anterior commissure where it forms a tongue. Certain specimens suggest that along the lateral commissure the shell may be sharply deflected ventrally before it is recurved dorsally, so that a raised margin may be developed. Ventral interarea low and apsacline with a well developed incurved umbo, apparently with an open pedicle foramen, and probably with the delthyrium closed by a narrow pseudodeltidium. Dorsal interarea extremely low, hypercline (or anacline), with a small notothyrium apparently closed by two chilidial plates which are fused to the cardinal process lobes. The socket ridges of the interior of the valve are continued across the dorsal interarea as two low ridges which converge beneath the insignificant dorsal umbo. Inner parts of the dorsal valve planate, margins not preserved. Outline alate, with greatest width along the straight hinge line; cardinal extremities pointed, anterior commissure broadly sulcate.

Surface of ventral valve with irregular concentric rugae, about 1 mm apart marginally, crossed by fine radial striations. Dorsal exterior poorly preserved.

VENTRAL INTERIOR—Muscle area longitudinally ovate, with a well-defined muscle bounding ridge. Adductors lanceolate, medianly mounted on a low ridge, diductors somewhat triangular. Two well developed crenulate teeth mounted each side of the delthyrium. Coarsely papillose 'genital area' each side of the muscle field. Ventral pallial sinuses apparently pinate, similar to those of *Leptaena*.

FIGURED SPECIMEN: M.3461 A-B, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 40 (rare), 43 (occasional), 46 (rare), 47 (rare), (49 rare), 54 (rare), 56 (rare).

REMARKS: The internal features of this form are very similar to those of *Leptaena emarginata* (Barr.) as described by Kozłowski (1929).

Fragmentary specimens of another leptaenid were collected in the Limestone Phase of the Coopers Creek Formation. This form appears to belong to *Leptaena*; its occurrence is recorded in Table 1 where it is identified as *Leptaena* sp. indet.

Family STROPHEODONTIDAE Caster

Genus *Leptostrophia* Hall 1892*Leptostrophia* sp. affn. *L. affinalata* (Gill)

(Pl. XXXII, fig. 1)

Affn. *Protopleptostrophia affinalata* Gill 1949, p. 100, Pl. 2, fig. 6; Pl. 3, fig. 19, 22.

DESCRIPTION:

EXTERIOR—Ventral valve slightly convex, semicircular or subquadrate in outline, with a long low apsacline interarea. Cardinal extremities quadrate or perhaps slightly alate; anterior commissure rounded. Delthyrium small, apparently closed by a very low pseudodeltidium. Surface poorly preserved but ornament apparently parvicostellate.

VENTRAL INTERIOR—Ventral process apparently very small and confined to the umbo of the valve. Muscle bounding ridges (= 'dental ridges' of Gill 1949, p. 100) diverging at an angle of about 45° and extending slightly less than half-way to the anterior commissure. Diductor scars triangular, set each side of the lanceolate adductors which in turn are separated by an obscure median ridge. 'Genital areas' each side of the muscle field coarsely papillose, with the pseudopunctae (= 'taleolae') smaller and radially aligned toward the shell margins. Hinge line denticulate for most of its length with about 5 or 6 denticles per mm.

Dorsal valve not identified in the collection.

MEASUREMENTS: M.3448, l. = 16 mm, w. (inferred) = 23 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3448, Loc. 47, Boola Beds (rare).

REMARKS: Gill (1948, 1949, 1950) has described various species in the Devonian genus *Protopleptostrophia* Caster from localities in Tasmania and Victoria, as well as referring the Yeringian species *Stropheodonta* (*Leptostrophia*) *alata* Chapman 1903 (p. 69, Pl. 11, fig. 6-7) to that genus. However, in all cases where the material permits positive identification, these records are based on species of *Leptostrophia*. In '*Protopleptostrophia affinalata*' Gill described the cardinal process as 'quadrifid' with two large central prongs on either side of which are much smaller ones. This type of structure, which Williams (1953a) showed to consist of the normal bilobed stropheodontid cardinal process and subsidiary socket plates which move adjacent to the cardinal process during the development of the leptostrophid stock, is completely characteristic of the genus *Leptostrophia*. On the other hand, *Protopleptostrophia* lacks the socket plates and so possesses a simple elongate bilobed cardinal process. It may be noted that Gill (1949) gives the time range of the genus *Leptostrophia* as Lower Devonian, but it appears first in lower Llandovery times (Williams 1951) and ranges through to the end of the Lower Devonian.

Although very similar to *L. affinalata*, from Sandy's Cr., the Boola form differs in a number of respects, certain of which, in terms of Williams's (1953a) concept of the development of the leptostrophid stock, suggest that the Boola form is the more primitive. Thus the figures of *L. affinalata* show the species to possess a well developed ventral process continued anteriorly as a well defined ridge. Strong process pits are also visible in the figures. In contrast to this in the Boola form the ventral process and process pits are poorly defined. A more significant distinction is that the hinge line is more closely denticulate in the Boola form. *L. alata* (Chapman) from the Yering Beds, apparently possesses more widely divergent muscle bounding ridges, but Chapman's description and figures make comparisons with that species difficult.

Leptostrophia sp. cf. **L. explanata** (Sowerby)

(Pl. XXXII, fig. 2-3)

Cf. *Leptaena explanata* Sowerby 1842, p. 409, Pl. 38, fig. 15.Cf. *Stropheodonta (Leptastrophia) explanata* (Sowerby) Maillieux 1936, p. 66-71 (*cum syn.*).? *Leptastrophia explanata* (Sowerby) Shirley 1938, p. 468, Pl. 41, fig. 7-9.? *Rhytostrophia shirleyi* Allan 1942, p. 146.**DESCRIPTION:**

EXTERIOR—Ventral valve large, slightly convex and semicircular in outline, with greatest width along the straight hinge line; cardinal extremities rounded to slightly alate. Interarea long, low and apsacline with a wide delthyrium partly closed by a low pseudodeltidium. Anterior commissure rounded.

Radial ornament parvicostellate, with strong irregularly spaced primary costellae about 1 or 2 mm apart toward the anterior commissure and usually separated by about 5 secondary costellae. Radial ornament crossed by subdued concentric rugae, which are more strongly developed toward the margins where they are about 2.5 mm apart.

VENTRAL INTERIOR—Ventral process small, buttressing the low pseudodeltidium, and discontinuous with a low median ridge which divides the ventral muscle field. Muscle bounding ridges high, diverging at an angle of about 90°, and fading anteriorly. They outline broadly triangular diductor impressions which are difficult to delineate from the narrow adductors. 'Genital area' on each side of the muscle field strongly tuberculate, with tubercles encroaching on the muscle bounding ridges. Hinge line denticulate for most of its length with the denticles spaced at about 4 per mm.

Dorsal valve not represented in the collection.

MEASUREMENTS: M.3449, l. = 29mm, w. (inferred) = 43 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3449 A-B, Loc. 36, Conglomerate Phase, Coopers Creek Formation.

REMARKS: Shirley (1938) identified this widespread European Lower Devonian species in the fauna of the Baton R. Beds, New Zealand. Allan (1942) renamed the Baton R. form '*Rhytostrophia shirleyi*' on the basis of the surface ornament in which subdued concentric growth rugae may be present, but as Williams (1953a) points out, this is of little consequence as a taxonomic feature in stropheodontids. Whether or not the New Zealand form is distinct from the European species is not clear so the single ventral valve from Tyers is compared with the better established European species. The ventral interior of *L. explanata* differs from that of other large species of *Leptostrophia* such as *L. magnifica* (Hall) in the very widely divergent muscle bounding ridges.

Genus Strophonella Hall 1879**Strophonella gippslandica** sp. nov.

(Pl. XXXII, fig. 4-5)

DIAGNOSIS: Large, gently resupinate *Strophonella* with a large ventral muscle field and very widely spaced radial costellae.

DESCRIPTION:

EXTERIOR—Ventral valve semicircular in outline with a long straight hinge line and slightly alate cardinal extremities. Profile gently resupinate, with the

posterior half of the valve convex. Ventral interarea long, low and apsacline, marked by faint vertical striations each side of the comparatively well developed umbo. Delthyrium partly closed by a low pseudodeltidium.

Surface of the valve with about 50 well spaced radial costellae which may reach over 2 mm apart before a further costella is intercalated. This ornament is apparently a modification of the typical stropheodontid parvicostellate ornament in which the secondary costellae have been lost leaving only the widely spaced primary costellae. This does not appear to be due merely to the preservation of the specimens as fine growth lines can be seen crossing the primary costellae.

VENTRAL INTERIOR—Cardinal process pits well defined on each side of the ventral process which supports the low pseudodeltidium and is prolonged anteriorly as a fine median ridge extending about half-way down the muscle field. Muscle impressions large and subquadrate, extending almost half-way to the anterior commissure and outlined anteriorly and laterally by a strong petaloid muscle bounding ridge. Adductor scars longitudinally ovate, extending about half-way down the muscle field and included by the diductors. Inner surface of the shell strongly papillose around the muscle area with the papillae finer and radially aligned marginally. Hinge line denticulate for about half the length with the denticles closely spaced at approximately 6 per mm. Dental lamellae absent.

MEASUREMENTS: M.3450, l. = 22 mm, w. = 35 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3450 (ventral valve); M.3451, both from Loc. 47, Boola Beds.

OCCURRENCE: Loc. 47 (occasional), 49 (rare), Boola Beds.

REMARKS: Although a dorsal valve of this species was not represented in the collection it was decided to name this form as it clearly is a species of *Strophonella* S.S. and is well characterized by the features of the ventral valve. Among the Australian species of *Strophonella* it is most closely allied to *S. australiensis* Gill 1948, from Tasmania, from which it differs most obviously in the proportionally larger ventral muscle field. A very closely related form has been collected from Melbourne Hill in the Yering Beds. It may be noted in passing that *Strophonella lyelli* Gill 1948 (p. 64, Pl. 8, fig. 32-4, 41) does not appear to be a species of *Strophonella* but probably represents a new stropheodontid genus.

Genus *Maoristrophia* Allan 1947

Maoristrophia sp.

(Pl. XXXIII, fig. 14-15)

DESCRIPTION:

EXTERIOR—Ventral valve slightly convex, semicircular in outline with quadrangular cardinal extremities and rounded anterior commissure and with greatest width along the straight hinge line. Interarea apsacline, comparatively high beneath the umbo which is incurved over the hinge line. Delthyrium open or perhaps closed by a low pseudodeltidium.

Surface with about 100 coarse, somewhat fascicostellate costellae which are marginally spaced at about 4 per mm.

VENTRAL INTERIOR—Low curved muscle bounding ridges arise each side of the shallow delthyrial cavity and diverge at angle of about 90°. These extend about one-third of the distance to the commissure and fade anteriorly. Muscle impressions obscure. Inner surface strongly papillose with the papillae radially aligned marginally.

Hinge line denticulate each side of the delthyrium for about one-third of the distance to the cardinal extremities. Denticles spaced at about 5 per mm and extending on to the ventral interarea as low ridges.

Dorsal valve unknown.

FIGURED SPECIMEN AND OCCURRENCE: M.3462, Loc. 36, Conglomerate Phase, Coopers Creek Formation.

REMARKS: The single fragmentary ventral valve clearly belongs to the genus *Maoristrophia* although it differs from the other species of the genus described by Allan (1947) and Gill (1952) in apparently lacking a well defined ventral sulcus.

Genus *Megastrophia* Caster 1939

Megastrophia (?) sp.

(Pl. XXXII, fig. 6)

One single ventral valve of this form was collected from Loc. 11, Limestone Phase, Coopers Creek Formation. It is figured here as it represents one of the few comparatively complete brachiopod valves collected from localities in the massive limestone. The specimen is questionably referred to the genus *Megastrophia* on the basis of its large size and strong convexity. The parvicostellate ornament, crossed by closely spaced, well developed growth lines, is also characteristic of that genus. The specimen also shows a tendency to develop irregular concentric rugae.

A further stropheodontid was represented in the collection by various fragments of 'cymostrophid' ornament. Although too fragmentary to warrant description, the occurrence of this form is shown in Table 1 where it is identified as *Cymostrophia* sp. indet.

Superfamily CHONETACEA Shrock & Twenhofel

Family CHONETIDAE Hall & Clarke

Genus *Chonetes* Fischer de Waldheim 1837

Chonetes cresswelli Chapman

(Pl. XXXII, fig. 7-9)

Chonetes cresswelli Chapman 1903, p. 77-8, Pl. 12, fig. 7.

Chonetes (Chonetes) cresswelli Chapman, Gill 1945, p. 134-5, Pl. 8, fig. 5.

Chonetes cresswelli Chapman, Gill 1951b, p. 60, Pl. 3, fig. 5; Fig. 2.

DESCRIPTION:

EXTERIOR—Ventral valve small, semicircular, with rounded anterior commissure, quadrate cardinal extremities and with greatest width along the straight hinge line or slightly anterior to it. Profile slightly convex. Ventral interarea extremely low and bearing 3 (or 4 ?) hollow, fairly slender spines each side of the umbo which are (at least the outer spines) directed back toward the umbo at an angle of about 45° to the hinge line. Delthyrium apparently open or modified by a low pseudodeltidium.

Surface marked by evenly spaced radial costellae with about 56 around the commissure of a large specimen and spaced at about 5 per mm.

VENTRAL INTERIOR—Two small teeth are mounted each side of the delthyrium and a short strong median septum extends from the umbo about one-quarter of the distance to the anterior commissure. Muscle impressions obscure. The

interior of the valve is strongly papillose with the papillae radially aligned marginally following the radial costellae.

Dorsal valve not represented in the collection.

MEASUREMENTS: M.3454, l. = 5 mm, w. = 8 mm; M.3455, l. = 6 mm, w. = 7 mm.

FIGURED SPECIMENS: M.3453-5, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 43 (occasional), 48 (rare), Boola Beds.

REMARKS: This form approaches closely *C. cresswelli* although the outer cardinal spines are directed in towards the umbo, a feature not seen typically in that species. The specimens, preserved as moulds, in general do not show the cardinal spines at all well, although 4 appear to be present on each side of the umbo. One specimen in particular (Pl. XXXII, fig. 7) appears to show only one spine on each side of the umbo and it was this particular specimen which was identified as *Chonetes ruddockensis* Gill elsewhere (Phillip 1960b). However, in all probability this appearance is due to the manner in which the specimen has been broken out of the matrix.

Fragments of a further species of *Chonetes* were also collected in the Limestone Phase of the Coopers Creek Formation. In the convexity of the ventral valve and the coarser surface ornament this form approaches more closely *C. robusta* Chapman. The material is too poor to warrant description but the occurrence of this form is recorded in Table 1 as *Chonetes* sp.



FIG. 14—*Uncinulus* (?) sp. Two transverse serial sections near the umbos of M.3456, separated by 1.2 mm. x 3 approx.

Superfamily RHYNCHONELLACEA Schuchert

Family CAMAROTOECIIDAE Schuchert & Le Vene

Genus *Uncinulus* Bayle 1878

Uncinulus (?) sp.

(Pl. XXXIII, fig. 1-3; Fig. 14)

DESCRIPTION:

EXTERIOR—Outline transversely elliptical with greatest width just posterior to midlength of the shell. Profile biconvex with the dorsal valve more strongly arched. Hinge line short with the cardinal margins rounded. Ventral valve with a well developed tongue so that the anterior commissure is broadly uniplicate.

Surface of both valves with about 50 rounded plications which become wider and

better defined as they approach the commissure. Both valves almost smooth in the umbonal regions. Usually about 10 plications in the ventral tongue.

MEASUREMENTS: M.3456, l. = 18 mm, w. = 25 mm, h. = 13 mm.

FIGURED SPECIMEN: M.3456, Loc. 15 Limestone Phase, Coopers Creek Formation.

OCCURRENCE: Loc. 1 (rare), 3 (rare), 11 (rare), 15 (occasional), 20 (rare), 21 (rare), 27 (rare), Limestone Phase; Loc. 31 (rare), 34 (rare), Conglomerate Phase, Coopers Creek Formation.

REMARKS: Although widely distributed through the Coopers Creek Formation, only one comparatively complete specimen of this form was collected, and even this specimen lacked the umbos of both valves. In an endeavour to arrive at some idea of the correct generic placement of this form the posterior end of the shell was ground to give two well spaced serial sections (Fig. 14). These proved difficult to interpret, but in the dorsal valve there is what appears to be a short median septum at the posterior end of a widely cleft hinge plate. A full interpretation of these internal features cannot be given till more suitable material is available for study. As they are known at present, a close similarity to the genus *Latonotoechia* Havlíček 1960 is indicated.

Large rhynchonellacids very similar in external morphology to the form are known from the Lower Devonian elsewhere in Victoria. The Lilydale form identified as *Eatonia* (*Eatonia*) affin. *bithynica* by Gill (1952) (= ? *Uncinulus stricklandi* Sowerby of Chapman 1903, p. 78) apparently represents a species of *Plethorhyncha* Hall and Clarke. Although the Tyers form appears to be a new species it seems best not to name it until its internal characters are better known and it can be properly compared with other Victorian forms.

Superfamily ATRYPACEA Schuchert & Le Vene

Family ATRYPIDAE Gill

Genus *Atrypa* Dalman 1828

Atrypa sp. cf. *A. reticularis* (Linnaeus)

(Pl. XXXIII, fig. 4-10)

? *Atrypa reticularis* var. *decurrens* Chapman 1913, p. 107, Pl. 11, fig. 13.

DESCRIPTION:

EXTERIOR—Shell rounded or longitudinally oval in outline, in lateral profile unequally biconvex with the dorsal valve more strongly convex. Greatest width usually half-way between the midlength of the shell and the short hinge line. Ventral sulcus variably developed; where strongly developed it becomes more marked anteriorly so that the anterior commissure may be strongly sulcate. The ventral umbo is prominent and strongly incurved so that the short interareas are obscured.

The surface is marked by strong rounded costae which are spaced at about 7 in 5 mm with an adult valve bearing about 60 such costae. They are crossed by well spaced growth lamellae which become more crowded toward the anterior commissure.

VENTRAL INTERIOR—Delthyrial cavity deep with a narrow furrow arising from the umbo. This expands into a triangular depression divided medianly by a low ridge. The depression broadens and shallows anteriorly and probably represents the site of the adductor muscles. They extend about half-way to the anterior end of

the ventral muscle field and are not clearly separated in front from diductor impressions. Diductor impressions large and flabellate, arising just anterior and lateral to the posterior end of the adductor impressions and extending about half-way to the anterior commissure. They appear to meet in front of the adductor scars. The whole muscle field is scored by radiating grooves. The teeth are strong, somewhat triangular, well separated and mounted toward the extremities of the short hinge line and supported by very short stout dental lamellae. Each side of the muscle field the floor of the valve is strongly pitted, probably representing the genital area.

DORSAL INTERIOR—Cardinal process absent with 2 stout divergent crural bases anteriorly outlining the rather deep sockets. The cardinalia, mounted on a posterior thickening of the shell, thus forms a sessile cleft hinge plate. Adductor scars large, longitudinally ovate and strongly incised and well separated medianly by a low ridge. Separation into anterior and posterior impressions not visible. The muscle field extends about half-way to the anterior commissure, with a strongly pitted genital area on each side. The muscle impressions are deeply but irregularly scored.

MEASUREMENTS: M.3457, l. = 17 mm, w. = 17 mm, h. = 12 mm.

FIGURED SPECIMENS: M.3457-8, Loc. 48, Boola Beds; M.3433, 59, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 1 (rare), 8 (rare), 11 (rare), 15 (rare), Limestone Phase; Loc. 31 (rare), 32 (occasional), 34 (occasional), 35 (rare), 36 (occasional), 37 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 47 (occasional), 49 (common), Boola Beds.

REMARKS: This form is very close to *Atrypa reticularis* (Linnaeus) as described by Alexander (1949). It differs from that species in its more round or longitudinally oval outline with the greatest width of the shell generally more toward the anterior. Internally the teeth are more widely separated and there appear to be minor differences in the ventral musculature. Although the form resembles closely many overseas forms externally (e.g. *Atrypa petosequa* Fenton and Fenton 1930, p. 7, Pl. 1, fig. 1-8), from the point of view of local stratigraphy, it would probably be best to recognize this form as a local subspecies of *A. reticularis*. This, however, cannot be safely done till the types of *A. reticularis decurrens* are restudied. The single small (ventral ?) exterior from Ruddock's Quarry figured by Chapman possesses a similar number of costae to a specimen of the Tyers form of the same dimensions. It would be unwise to consider the two forms to be identical on the basis of this alone, so the matter is best left in abeyance. Chapman records his variety from Loyola, probably from a similar horizon to that of the Boola Beds.

Atrypa fimbriata (Chapman)

(Pl. XXXIV, fig. 1-3)

Atrypa fimbriata Chapman 1913, p. 109, Pl. 11, fig. 15.

Karpinskya ? fimbriata (Chapman) Gill 1942, p. 1.

non *Atrypa fimbriata* (Phillips) Sowerby 1840, p. 16, Pl. 617, fig. 4.

DESCRIPTION:

EXTERIOR—Ventral valve moderately convex with short low interarea and strongly incurved umbo. Outline longitudinally oval with greatest width just anterior to the hinge line. Anterior commissure rounded.

Surface marked by about 10 or 12 rounded radial ribs which are strongly developed medianly but fade laterally. These are crossed by well spaced, high growth

lamellae which become progressively further apart away from the umbos and are over 1 mm apart around the anterior commissure. The ribs appear to have a tendency to be continued as marginal spines, but these are not preserved in either of the Tyers specimens.

VENTRAL INTERIOR—Delthyrial cavity deep with 2 small teeth mounted on short thick diverging dental lamellae. Muscle impressions obscure with the inner surface of the valve marked by the internal reflection of the strong surface ornament.

Dorsal valve not represented in the collection.

MEASUREMENTS: M.3463, l. = 7 mm, w. = 6 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3463, Loc. 47, Boola Beds.

REMARKS: The 2 ventral valves from Tyers agree closely with Chapman's figure of *A. fimbriata* although the concentric lamellae are closer in the Tyers specimen. Gill (1942) questionably referred Chapman's species to the Lower Devonian genus *Karpinskya* on the basis of the short median septum in the dorsal valve. The species, however, is typical of the genus *Atrypa*, and may be placed with those placed in the genus *Spinatrypa* Stainbrook 1951 on the basis of the surface ornament.



FIG. 15—*Plectatrypa australis* sp. nov. Transverse serial sections. The number beneath each figure refers to the distance each section is from the posterior end of the shell. $\times 3$.

Genus *Plectatrypa* Schuchert & Cooper 1930

Plectatrypa australis sp. nov.

(Pl. XXXIV, fig. 5-9; Fig. 15)

DIAGNOSIS: *Plectatrypa* with moderately coarse plications and bearing about 5 plcae in the broad ventral sulcus.

DESCRIPTION:

EXTERIOR—Outline rounded to subquadrate with a prominent ventral umbo incurved over the short hinge line. Position of greatest width variable but usually about midlength of the shell. Lateral profile equally biconvex. Ventral valve with a well defined sulcus which becomes more strongly developed anteriorly so that the anterior commissure is broadly sulcate.

Both valves marked by fairly low rounded fasciculate plications. Ventral sulcus with 4 or, more usually, 5 plications. A large valve may bear up to 30 plications marginally which are spaced at about 1 or 2 per mm around the commissure. Away from the median zone of the shell the plications become progressively recurved toward the lateral commissure. Radial ornament crossed by fine, regularly spaced growth lines about 4 per mm.

VENTRAL INTERIOR—Ventral interior with strong rounded teeth which articulate with deep dorsal sockets and are supported beneath by short strong diverging dental lamellae which originate a short distance from the umbo. Muscle area poorly defined, apparently triangular in shape arising from the deep delthyrial cavity and extending about one-third the distance to the anterior commissure.

DORSAL INTERIOR—Notothyrial cavity deep with a low median ridge arising just anterior of the umbo and extending a short distance down the floor of the valve. Hinge plate widely cleft with deep sockets bounded laterally by the valve wall and medianly by strong crural bases. Arising from the anterior end of the crural bases are the ribbon-like crura which apparently supported the spires. Spires not observed in any specimens.

MEASUREMENTS: M.3471, l. = 13 mm, w. = 14 mm, h. = 6 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3471, M.3469, Loc. 48; M.3470, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 47 (rare), 48 (occasional), Boola Beds.

REMARKS: This species is very similar internally to *P. marginalis* (Dalman) as described by Poulson (1943). The only distinction which can be seen is in the thicker crural bases and dental lamellae which appear to be continued further anteriorly in *P. australis*. The surface ornament, however, characterizes the new species. It is coarser than that of *P. marginalis* but not so coarse as that of *P. groenlandica* (Poulson 1943, p. 46, Pl. 5, fig. 17-23) from the Silurian of Greenland. Thus it approaches more closely some of the North American species, in particular *Plectatrypa brownsportensis* Amsden 1949 (p. 64, Pl. 34, fig. 2-3, 8-10)

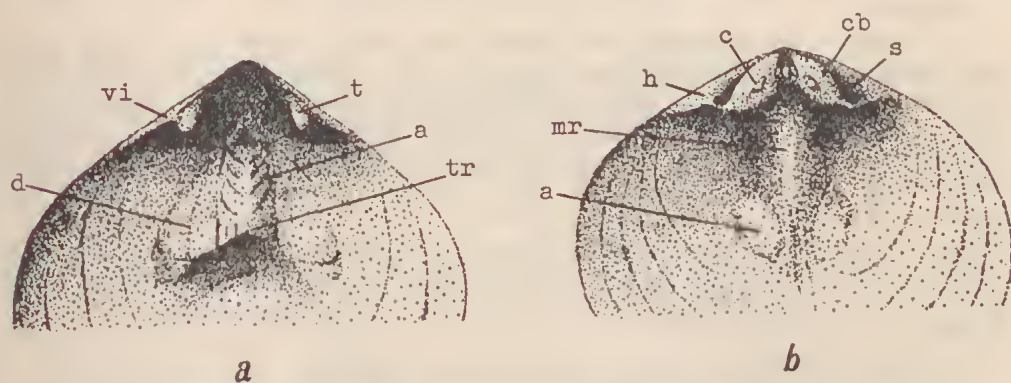


FIG. 16—*Lissatrypa lenticulata* sp. nov. (a) Ventral interior from latex impression of M.3465; (b) Dorsal interior from latex impression of holotype M.3467. a: adductor muscle impression, d: diductor muscle impression, t: tooth, tr: apex of triangular muscle platform, vi: ventral interarea, c: crus, cb: crural bases, h: cleft hinge plate, mr: median ridge, s: socket. x 5 approx.

from which it may be distinguished by the presence of a greater number of plications in the ventral sinus. The genus *Plectatrypa* is represented elsewhere in Australia in *Atrypa marginalis* Dalman of Mitchell and Dun (1920), from the Silurian of Yass, N.S.W. *Plectatrypa* appears to be confined to rocks of Silurian age elsewhere in the world.

Genus *Lissatrypa* Twenhofel 1914

Lissatrypa lenticulata sp. nov.

(Pl. XXXIV, fig. 4, 17-21; Fig. 16)

DIAGNOSIS: *Lissatrypa* with extremely low interareas and a poorly developed dorsal septum.

DESCRIPTION:

EXTERIOR—Shells with rounded to longitudinally oval outline, sometimes almost subquadrangular. Lateral profile equally biconvex. Hinge line short with rounded cardinal extremities; greatest width of shell usually about midlength or slightly posterior. Ventral interarea extremely low and curved, probably with an open delthyrium and perhaps with an open pedicle foramen at the apex of the comparatively well developed ventral umbo. Dorsal interarea virtually absent. Ventral valve with a variably developed sulcus so the anterior commissure may be widely sulcate.

Surface of both valves with well spaced growth lamellae about 1 mm apart but becoming more distant anteriorly. These are present also on the inner surfaces of the valves.

VENTRAL INTERIOR—Delthyrial cavity bounded by 2 lateral callosities which buttress the well developed teeth mounted just anterior to the interarea. A high triangular muscle platform arises just anterior of the umbo and extends about one-quarter of the distance to the anterior commissure. Mounted medianly on this are 2 elongate adductor muscle tracks while to each side larger, more flabellate deductor scars are present. Vague traces of the ventral pallial sinuses can be seen arising from the anterior of the muscle platform. Their pattern is pinnate, similar to that of *Coelospira*.

DORSAL INTERIOR—Dorsal interior with a heavy cleft sessile hinge plate. The crural bases are high and widely divergent and are incurved back over the deep elongate sockets which they define anteriorly. They bear two small projections on their apices which probably represent the crura. Nestled between the crural bases just anterior to an umbonal depression is a small protuberance. This is seen only in some of the specimens. The hinge plate is continued anteriorly as a low broad median ridge which extends about one-third of the distance to the anterior commissure. 2 small longitudinally ovate adductor scars are mounted close together each side of this median ridge at its anterior end. They tend to constrict the anterior end of the median ridge which, between the muscle impressions, may bear a shallow furrow.

MEASUREMENTS: M.3467, l. = 12 mm, w. = 12 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3467 (dorsal valve); M.3464-6, 8, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 25 (rare), Mudstone Phase, Coopers Creek Formation; Loc. 39 (rare), 40 (occasional), 41 (rare), 42 (rare), 43 (common), 44 (rare), 45

(rare), 46 (rare), 47 (rare), 50 (rare), 51 (occasional), 52 (occasional), 53 (rare), 57 (rare), Boola Beds.

REMARKS: This rather variable species agrees closely with the internal features of *Lissatrypa atheroidea* Twenhofel, the generally accepted type species of *Lissatrypa*, as described by Kirk and Amsden (1952). One distinction is in the septum of the dorsal valve, which in *L. lenticulata* is represented by a broad low ridge. This feature, together with the extremely low interareas, serves to distinguish *L. lenticulata* from other species of *Lissatrypa*. Otherwise, the species is very close to such North American forms as *L. decaturensis* Amsden 1949 (p. 64, Pl. 9, fig. 16-23) from the Silurian of Tennessee.

The small projections mounted on the apices of the crural bases in some specimens of *L. lenticulata* probably represent the crura (Fig. 16b). Thus their location is similar to those of *L. atheroidea* as shown by Kirk and Amsden. On the other hand Kozłowski (1929, Fig. 54) shows the crura arising from the outer sides of the crural bases in his *L. leprosa*.

The genus *Tyrothyris* Öpik 1953, based on *T. tyro*, from the Llandovery of Heathcote, Victoria, is a genus which approaches *Lissatrypa* very closely in its internal features, but the two species described by Öpik in this genus were considered to be punctate. Although his material was preserved as moulds, there appears to be no *a priori* reason for doubting Öpik's interpretation; all known punctate stocks (excepting the terebratuloids) closely parallel a related impunctate stock and punctate *Atrypas* are known elsewhere (e.g. *Punctatrypa* Havlíček 1953). The shell material of *Lissatrypa lenticulata*, needless to say, is impunctate.

In this context mention should be made of *Nucleospira australis* McCoy 1874. Öpik (1953) has suggested that one of the figured specimens is perhaps a species of *Tyrothyris*. It could also represent a species of *Lissatrypa*.

Atrypoidea Mitchell and Dun 1920, a genus of smooth *Atrypa* from the Silurian of Yass, N.S.W., although imperfectly known, in all probability is a synonym of the genus *Atrypella* Kozłowski 1929.

Superfamily SPIRIFERACEA Waagen

Family SPIRIFERIDAE King

Genus *Eospirifer* Schuchert 1913

Eospirifer sp. affin. *E. togatus* (Barrande)

(Pl. XXXIV, fig. 14-16)

Affin. *Spirifer togatus* Barrande 1848, p. 167, Pl. 15, fig. 2.

Affin. *Eospirifer togatus* (Barrande), Shirley 1938, p. 477, Pl. 43, fig. 8-14; Havlíček 1959, p. 41, Pl. 7, fig. 1-6 (*cum syn.*).

DESCRIPTION:

EXTERIOR—Ventral valve large and transversely oval in outline and moderately convex with a prominent umbo incurved over the short interarea. Interarea concave, fairly high and triangular with a large, apparently open delthyrium. Greatest width usually about midlength of the shell. Ventral valve with a wide sulcus so that the anterior commissure is broadly sulcate. Flanks of the shell lacking plications. Surface with broad rounded costellae spaced at about 20 in 5 mm.

VENTRAL INTERIOR—Ventral interior with 2 extremely long high dental lamellae which extend three-quarters of the distance to the anterior commissure and bear small teeth adjacent to the interarea. Muscle impressions obscure on the floor

of the deep delthyrial cavity. Some specimens show a low ridge at the posterior end of the delthyrial cavity whilst others show a vague trace of large flabellate diductors (?) between the anterior ends of the dental lamellae.

Dorsal valve with a broad fold corresponding with the ventral sulcus; internal features unknown.

MEASUREMENTS: M.3475, l. = 14 mm, w. = 19 mm.

FIGURED SPECIMENS: M.3474, 6, Loc. 48; M.3475, Loc. 49, Boola Beds.

OCCURRENCE: Loc. 11 (rare), 15 (rare), 26 (rare), Limestone Phase, Coopers Creek Formation; Loc. 43 (rare), 48 (occasional), 49 (rare), Boola Beds.

REMARKS: This species is identified with *Eospirifer togatus* on the basis of the strong dental lamellae, the absence of gentle ribs on the flanks of the shell and the rounded ventral sulcus. In fact the dental lamellae are stronger than in Barrande's species and the surface ornament is slightly coarser. It seems best not to recognize this form as a new species till the internal features of the dorsal valve are known.

Eospirifer parahentius Gill 1950 (p. 247, Pl. 1, fig. 1-6) from the Bell Shale, Tasmania, appears to represent a closely related species with shorter dental lamellae.

All the various fragmentary specimens of *Eospirifer* from Tyers are placed in the one form, but it is possible that more than one species is represented in the collection.

Genus *Delthyris* Dalman 1828

Subgenus *Howellella* Kozlowski 1946

Delthyris (*Howellella*) *scabra* sp. nov.

(Pl. XXXIV, fig. 10-13, 22; Pl. XXXV, fig. 18)

DIAGNOSIS: Small *Howellella* with weak dental lamellae, a high ventral interarea, and a deep, broadly rounded ventral sulcus with usually 3 lateral plications on each side of the sulcus, the outer 2 of which are poorly defined.

DESCRIPTION:

EXTERIOR—Outline transversely oval with a straight hinge line about two-thirds the maximum width of the shell which is approximately at the midlength. Cardinal extremities well rounded; anterior commissure gently sulcate. Lateral profile biconvex with the ventral valve deeper and more strongly arched. Ventral umbo prominent and incurved over the high concave ventral interarea which has a wide, apparently open delthyrium. Dorsal umbo insignificant. Ventral valve with a deep smooth sulcus about one-third the width of the shell; dorsal valve with a corresponding high fold. Both of these originate from the umbos of the respective valves. Lateral plications variable in number, usually with 3 plications on each side of the ventral sulcus and 2 on each side of the dorsal fold, but the outer plications are low and poorly defined. Surface of both valves with fine concentric growth lamellae spaced at about 5 per mm with transversely mounted spines spaced at about 16 per mm in their interspaces.

INTERIOR—Ventral valve with 2 very short, somewhat oblique dental lamellae bounding the deep delthyrial cavity. Dorsal valve with 2 extremely short, closely mounted crural bases each side of the dorsal umbo. Cardinal process apparently absent. Musculature obscure.

MEASUREMENTS: M.3472, l. = 9 mm, w. = 10 mm, h. = 5 mm.

TYPE AND FIGURED SPECIMENS: Holotype M.3472, Loc. 49; M. 3473, Loc. 47, Boola Beds; M.3462, Loc. 36, Conglomerate Phase.

OCCURRENCE: Loc. 36 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 43 (rare), 49 (occasional), Boola Beds.

REMARKS: Talent (1956b) recognized 4 species in a collection of a dozen or so specimens of *Howellella* from the Toongabbie limestones which are of a similar horizon to that of the Coopers Creek Formation. I would consider that only 2 species are present in the Toongabbie collection—the first represented by *Howellella lirata* Talent and *H. latisulcata* Talent, the second by Talent's *Howellella* cf. *H. (?) gibbosa* (Barrande) and his *Howellella* sp. indet. This second species is probably *D. (H.) scabra*, although no direct comparison has been made between the Tyers and Toongabbie specimens, and the Toongabbie forms are not figured. *Spirifer gibbosus* Barrande is apparently a species of *Delthyris* S.S., although Havlíček (1959) has proposed a new genus *Ivanothyris* for its reception.

D. (H.) scabra is perhaps closest to *D. (H.) vauuxemi* (Hall) (Howell 1947, Pl. 1, fig. 1-9), although this species may bear more lateral plications and also possesses a faint plication in the sulcus. The Bohemian species described by Barrande (1879) with which *D. (H.) scabra* may be compared on the basis of external morphology (e.g. *Spirifer insocius*) are placed in different genera by Havlíček (1959).

The feature which distinguishes *Delthyris* from *Howellella*, the presence of a median septum in the dorsal valve, does not appear to be a very stable feature in spiriferids (*vide* Boucot 1957) so here *Howellella* is regarded as a subgenus of *Delthyris*. On the other hand Havlíček (1959), in his classification of spirifers, has separated the two groups at the subfamily level, as he places *Howellella* in the Hysterolitinae. Another genus which appears out of place in that subfamily is *Spinella* Talent 1956, which clearly should be placed near the genus *Spinocyrtia*.

D. (H.) scabra appears to be a variable species in the number of lateral plications. 4 may be seen on the flanks of the ventral valve of the holotype, although the outer one is very poorly defined. In general, however, 3 are present on the flanks of the ventral valve and 2 on the flanks of the dorsal valve.

Superfamily ROSTROSPIRACEA Schuchert & Le Vene

Family MERISTELLIDAE Hall & Clarke

Genus *Meristella* Hall 1860

Meristella sp. indet.

(Pl. XXXV, fig. 3)

DESCRIPTION: Ventral valve longitudinally oval in outline with moderately convex lateral profile. Hinge line very short with rounded cardinal extremities. Surface with obscure growth lines. Ventral interior with 2 short dental lamellae bounding the deep delthyrial cavity. A small triangular muscle platform is present about one-third of the distance to the anterior commissure. The ventral valve has a length of 4 mm and a width of 3 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3488, Loc. 43, Boola Beds.

REMARKS: The single small ventral valve clearly represents a species of *Meristella*, but identification at a specific level is not possible.

Family NUCLEOSPIRIDAE Davidson

Genus *Nucleospira* Hall 1857*Nucleospira* sp.

(Pl. XXXV, fig. 1)

? *Nucleospira* cf. *marginata* Maurer, Gill 1942, p. 43-4, Pl. 4, fig. 5; Pl. 5, fig. 6.

DESCRIPTION:

EXTERIOR—Ventral valve transversely oval in outline and gently concave in profile. Hinge line short with a fairly prominent umbo. A faint sulcus is present in the ventral valve so the anterior commissure is gently sulcate. Surface poorly preserved and with only irregularly spaced growth lines visible.

VENTRAL INTERIOR—Two strong teeth are mounted each side of the shallow delthyrial cavity. A long straight median septum arises from just anterior of the umbo and extends almost to the commissure, although it is poorly defined for the anterior half of its length. Musculature obscure.

Dorsal valve unknown.

MEASUREMENTS: M.3477, l. = 7 mm, w. = 8 mm.

FIGURED SPECIMEN: M.3477, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 43 (rare), 47 (rare), Boola Beds.

REMARKS: This small species of *Nucleospira* appears to be closely comparable to the Yeringian form identified as *N. cf. marginata* Maurer by Gill (1942). A similar form from the Lyell Highway, Tasmania, was named *N. megalorhyncha* by Gill (1948, p. 62, Pl. 8, fig. 27-28, 42-43). Without further material more positive identification of the Tyers form is not possible.

PHYLUM MOLLUSCA

Class LAMELLIBRANCHIATA

Family LEIOPTERIIDAE Maillieux

Genus *Actinopteria* Hall 1883*Actinopteria* sp.

(Pl. XXIX, fig. 12)

DESCRIPTION: Small, obliquely pterinoid left valve, with body of shell more strongly differentiated from the posterior wing than from the small anterior wing. Anterior wing much more rounded than posterior wing; hinge line straight, with umbo well toward the anterior. Umbo slightly incurved over the hinge line and directed forward. Body of shell inflated, making an angle of about 35° to the hinge line. Ligament area very thin, extending the length of the hinge line. One thin, slightly oblique posterior lateral tooth extending to well down the posterior wing, obscured by matrix near the umbo.

Surface ornament of strong radial ribs which on the posterior part of the body of the shell are approximately 0.3 mm apart, with their interspaces about one-quarter their diameter. On the posterior wing the radial ribs are closer and less strongly developed, about 0.2 mm apart. Radial ornament crossed by strong, evenly spaced growth lamellae approximately 0.15 mm apart, giving a markedly reticulate appear-

ance to the shell. Where the two sets of ornament intersect there is a tendency for nodes to develop.

Right valve unknown.

MEASUREMENTS: Length along hinge 9 mm, maximum height 6 mm.

FIGURED SPECIMEN: M.3414, Loc. 36, Coopers Creek Formation.

OCCURRENCE: Loc. 36 (rare), Conglomerate Phase, Coopers Creek Formation; Loc. 47 (rare), Boola Beds.

REMARKS: The strongly reticulate ornament of this form is very similar to that of species of *Asselberghsia* Maillieux 1931. However, the internal characters, as far as they can be assessed, are in complete agreement with *Actinopteria*.

The very oblique body chamber in the specimen illustrated appears to have been accentuated by shearing of the enclosing rock.

Family NUCULIDAE Adams

Genus *Nuculites* Conrad 1841

Nuculites sp.

(Pl. XXIX, fig. 9-10)

DESCRIPTION: Left valve small, well rounded and inflated, umbo slightly toward the anterior, directed forward, not prominent; valve with greatest height directly beneath the umbo. A well marked partition extends from just anterior of the umbo to about two-thirds the distance to the ventral margin. This partition is curved with the convex surface to the anterior. Dentition and musculature unknown. Surface marked by a few, ill-defined growth ridges.

MEASUREMENTS: Maximum length 5 mm, maximum height 4 mm.

FIGURED SPECIMEN AND OCCURRENCE: M.3397 A-B from Loc. 43, Boola Beds.

REMARKS: This form is represented in the collection by a single left valve, preserved as an internal and external mould. The strongly curved character of the anterior partition separates this form from other Victorian species of *Nuculites*.

Family CTENODONTIDAE Dall

Genus *Ctenodonta* Salter 1851

Ctenodonta (*Ctenodonta*) sp. affin. *C. melbournensis* (Chapman)

Affin. *Nuculana melbournensis* Chapman 1908, p. 28, Fig. 29-31.

DESCRIPTION: Small, ovate, biconvex shells with umbos fairly prominent; anterior end distinctly shorter than posterior. Umbos incurved over hinge line and pointing slightly forward. Greatest height of valves directly below the umbos. Dentition of numerous taxodont teeth which pass without interruption beneath the umbo; from the posterior end of the hinge line they decrease greatly in size to beneath the umbo. About 13 teeth posterior to the umbo but apparently very few anterior to it. Muscle scars not apparent. Surface covered by fine, irregularly spaced, growth lines.

MEASUREMENTS: Left valve length 5.5 mm, height 4 mm.

OCCURRENCE: Loc. 43, Boola Beds (rare).

REMARKS: The present species is but half the size of Chapman's species from the Melbourne Beds, but the description could be based on immature specimens.

Subgenus *Praectenodonta* subgenus nov.(= *Tancrediopsis* Beushausen *sensu* McLearn 1924)

DIAGNOSIS: Rostrate forms with taxodont dentition and surface ornament of broadly spaced, strong growth lamellae.

TYPE SPECIES: *Palaeoneilo raricostae* Chapman 1908, p. 34-5, Pl. 3, fig. 50; Gill 1949, Pl. 3, fig. 11, and described below.

REMARKS: McLearn (1924) has placed the three closely related Victorian species *Palaeoneilo victoriae*, *P. spectabilis* and *P. raricostae* in the genus *Tancrediopsis* Beushausen 1895, originally proposed as a subgenus of *Ctenodonta* Salter. This change in generic position was accepted without comment by Gill (1949) for *P. raricostae*. As type of the genus McLearn designated *Ctenodonta* (*Tancrediopsis*) *subcontracta* Beushausen. This designation, however, proves to be invalid as Beushausen (1895, p. 70) clearly states as types *Ctenodonta contracta* Salter and *C. sulcata* Hisinger, both fairly typical species of *Ctenodonta* approaching closely *Ctenodonta nasuta* (Hall), the generally accepted type species of the genus. Thus *Tancrediopsis* Beushausen may be regarded as a synonym of *Ctenodonta* Salter (c.g. Maillieux 1936).

Even with *Ctenodonta* (*Tancrediopsis*) *subcontracta* Beushausen as type of the genus it is extremely doubtful if it can be used in the sense of McLearn. When McLearn placed the Victorian species in *Tancrediopsis*, the dentition beneath the umbos was unknown in all three species, so that solely on the basis of their shape and ornament they were better left in the genus *Palaeoneilo* Hall. Specimens of *P. raricostae* are now available which show the dentition. This consists of a row of taxodont teeth which pass without interruption beneath the umbos, and thus the closely related Victorian forms must be placed with *Ctenodonta*. The rostrate shape and ornament of strong growth lamellae, however, precludes their placement in *Ctenodonta* S.S., so a new subgenus is proposed for their reception. For completeness a description of the type species *P. raricostae* Chapman is given below.

The three species described by McLearn in *Tancrediopsis* cannot with certainty be placed in *Praectenodonta* as their dentition beneath the umbos is unknown. Their general appearance, however, strongly suggests inclusion in the subgenus. *Praectenodonta* thus is known from the Upper Silurian and Lower Devonian of Victoria, doubtfully from the Silurian of Canada, and perhaps even from the Upper Silurian of Scotland in '*Palaeoneilo* cf. *victoriae* Chapman' of Lamont (1948).

In passing it may be noted that *Ctenodonta* Salter 1851 is a junior synonym of *Tellinomya* Hall 1847. This issue is discussed in detail by Williams and Breger (1916, p. 156 *et seq.*). The name *Ctenodonta* is used here, as has been the practice of most authors this century.

Description of *P. raricostae* Chapman*Ctenodonta* (*Praectenodonta*) *raricostae* (Chapman)

(Pl. XXIX, fig. 11, 13-15, 17)

Palaeoneilo raricostae Chapman 1908, p. 34-5, Pl. 3, fig. 50.*Tancrediopsis raricostae* (Chapman) McLearn 1924, p. 100; Gill 1949, Pl. 3, fig. 11.? *Tancrediopsis raricostae* (Chapman) Gill 1949, p. 109-10, Pl. 2, fig. 4; Pl. 3, fig. 5, 8.

DESCRIPTION: Medium sized, biconvex, rostrate shells, with length more than twice the height. Umbos prominent, half-way along the shell, incurved over the hinge line. Anterior margin well rounded, dorsal margin straight, with shell tapering posteriorly to the subangular posterior margin. Shallow sinus present extending

from behind the umbos to posterior margin. Surface covered by broadly spaced, concentric lamellae which become progressively further apart away from the umbo. In the interspaces between the lamellae are present fine growth lirae about 10 of which are present in the larger interspaces. In a shell 28 mm long the strong growth lamellae are less than 0.2 mm apart near the umbo, while marginally they are greater than 0.6 mm apart. Ligament area and musculature not apparent.

Hinge plate widest toward its extremities, contracted beneath the umbos, covered by an uninterrupted row of taxodont teeth, which are larger and further spaced away from the umbo (about 0.4 mm apart); passing beneath the umbo they become smaller and closer together till they are less than 0.1 mm apart. Usually about 15 teeth visible each side of the umbo.

FIGURED SPECIMENS AND OCCURRENCE: This species is widely distributed through the Yering Beds. The holotype (P. 7918), from Simmons Bridge, has been illustrated by Gill (1949, Pl. 3, fig. 11). Figured here are P. 17418 from Killara Tunnel and P. 17419-20 from Syme's Homestead, from the Yering Beds.

REMARKS: In the orientation of this species the narrower, more contracted end of the shell is regarded as the posterior, following Wilson's (1956) discussion of the orientation of related forms.

The attitude of the valves in the specimen illustrated in Pl. XXIX, fig. 17 suggests that the species possessed an external ligament posterior to the umbos.

Ctenodonta (Praectenodonta) victoriae (Chapman)

(Pl. XXIX, fig. 16)

Palaconeilo victoriae Chapman 1908b, p. 33, Pl. 3, fig. 46-9.

Tancrediopsis victoriae (Chapman), McLearn 1924, p. 100.

DESCRIPTION: Moderate sized, biconvex, rostrate shells, with prominent umbos apparently incurved over the hinge line. Anterior end well rounded with the shell tapering posteriorly to the subangular posterior margin. A shallow sinus extends from immediately posterior of the umbos to the posterior margin. A narrow platform extends from just posterior of the umbos well down the postero-dorsal margin; this could represent an external ligament area. Surface with comparatively close growth lamellae, in the interspaces of which there may be up to four fine growth lirae.

Internal features not preserved.

FIGURED SPECIMEN: M.3398, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 43 (occasional), 45 (rare), 48 (rare), Boola Beds.

REMARKS: This species is characteristic of the Melbourne Beds, although Gill (1940, p. 254) records it from Ruddock's Quarry and Hull Rd, within the Yering Beds. It differs from *C. (P.) raricostae* in its smaller size and much more closely spaced growth lamellae.

Family PLEUROPHORIDAE Dall

Genus *Cypricardinia* Hall 1859

Cypricardinia sp.

(Pl. XXXIV, fig. 1-3)

A few valves of a species of *Cypricardinia* were collected from Loc. 47 in the Boola Beds. The surface ornament of this form, in which traces of subradial striations arranged in a chevron pattern are present between the growth lamellae,

suggests that it belongs to the group of *Cypricardinia contexta* Barrande, but more material is necessary before positive identification can be made.

PHYLUM ARTHROPODA

Class TRILOBITA

Family CHEIRURIDAE Salter

Genus *Cheirurus* Beyrich 1845

Subgenus *Cheirurus* Beyrich

Cheirurus (*Cheirurus*) sp.

(Pl. XXXV, fig. 5)

DESCRIPTION: Cranidium wider than long with the fixed cheeks almost twice the width of the occipital ring. Glabella expanding forwards, with the frontal lobe rounded and tumid, about two-thirds as long as wide, and delineated posteriorly by 2 strong, slightly backward directed lateral glabellar furrows. These are strongly incised for over three-quarters of the way to the axis of the glabella and are continued across the axis as a gentle furrow. The second lateral glabellar furrows are similar to the first. Pre-occipital furrow curved backwards and extending about two-thirds of the distance to the axis. Occipital furrow similar in length to the pre-occipital furrow, but with a slight anterior inflection medianly. The median ends of the occipital and pre-occipital furrows delimit a subquadrate depression across the glabella. The pre-occipital lobes each bear a small tubercle towards their axial margins. Occipital ring short, poorly defined across the median part of the glabella, and bearing a low median tubercle. Glabella smooth apart from the tubercles mentioned. Fixed cheeks wide, posteriorly bounded by a narrow border which joins the wider lateral border. Facial suture proparian, with the anterior branch arising from each side of the widest part of the frontal glabellar lobes, extending back close to the glabella, with the lateral branch with a slight forward inclination. Palpebral lobes well developed, continuous with low eye ridges. Fixed cheeks strongly pitted, with the pitting markedly coarser laterally. Glabella without an anterior margin.

FIGURED SPECIMEN AND OCCURRENCE: M.3481, Loc. 55, Boola Beds.

REMARKS: This single large cranidium is clearly referable to *Cheirurus* S.S. on the basis of the wide fixed cheeks, and the discontinuity of the lateral glabellar furrows across the glabella. It appears to represent a new species characterized by its large size, the complete absence of any anterior border in front of the glabella, and the well developed palpebral lobes. In the general plan of the cranidium it perhaps resembles most closely *C. quenstedti* Barrande (Prantl and Přibyl 1947, Pl. 1, fig. 1) from the Silurian of Bohemia. The single large specimen was collected by Dr D. E. Thomas during a brief visit to the area.

Cheirurus S.S. has been recorded before in Australia in the glabella identified as such by Gill (1948, p. 67, Pl. 8, fig. 6) from Tasmania.

Subgenus *Crotalocephalus* Salter 1853

Cheirurus (*Crotalocephalus*) *silverdalensis* Etheridge and Mitchell

(Pl. XXXIV, fig. 1; Pl. XXXV, fig. 1-2, 14, 15)

Crotalocephalus silverdalensis Etheridge and Mitchell 1917, p. 490-1, Pl. 24, fig. 10; Pl. 25, fig. 1-3, 9.

DESCRIPTION: Glabella about twice as long as wide with an expanded tumid frontal lobe. First and second lateral glabellar furrows similar, deeply incised, with a slight backward inclination, and shallowing slightly across the axis. Pre-occipital furrow slightly curved, backwardly directed at an angle of about 60° to the midline of the glabella. Occipital furrow transverse to the glabella marginally but towards the axis it has a sharp forward inflection. Occipital ring fairly long and expanded anteriorly in the median part of the glabella; median tubercle very small. Surface of the glabella with very small well spaced granules. Fixed cheeks fragmentary, covered with coarse pits.

Hyperstone elongate with a well-delineated, domed median body which narrows posteriorly. Border furrow deep with posterior border wide and flat. Anterior wings high and lateral maculae located well to the posterior of the median body. Surface smooth.

Pygidium wide and short with 3 well defined axial rings and a smaller posterior raised area. Pleural ridges well defined toward the axis with the anterior 2 pairs originating opposite the central axial ring, while the posterior pair are opposite the posterior axial ring, are very much smaller and have a strong backward inclination. There are 6 flat tapering marginal spines, the axial pair of which is small and close together, while the outer pair is also reduced in size.

FIGURED SPECIMENS: M.3477, 9, Loc. 43; M.3463, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 43 (occasional), 47 (rare), 48 (rare), 49 (rare), Boola Beds.

REMARKS: In the details of the glabella the Tyers form agrees very well with *C. (C.) silverdalensis* from the Silurian of Yass, N.S.W. Thus the pre-occipital furrows have a stronger backward inclination whereas the occipital furrows are more transverse than in such species as *C. (C.) sternbergi* Boeck. Etheridge and

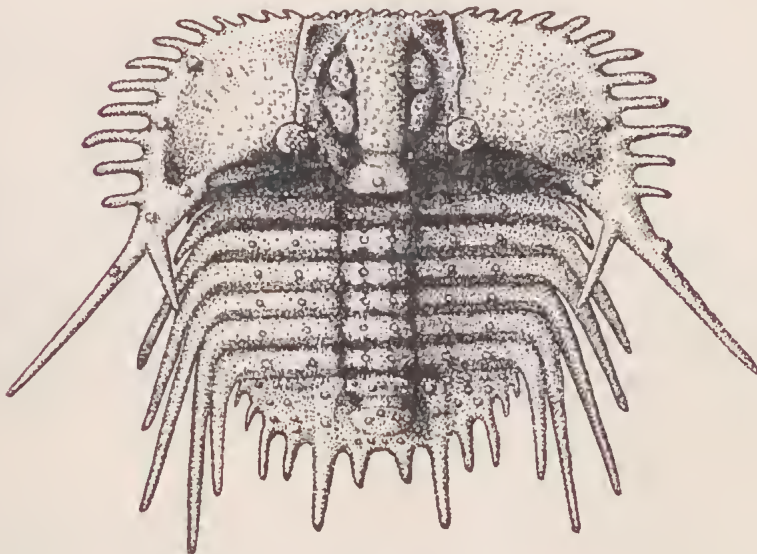


FIG. 17—Reconstruction of *Leonaspis bispinosa* sp. nov. The number and arrangement of thoracic segments is based on *L. williamsi* Whittington. $\times 3$ approx.

Mitchell describe the single poorly preserved pygidium they place in their species as possessing 'centrally a short, flat, rounded spine'. Either they misinterpreted the specimen or the form referred to does not belong to *Crotalocephalus*. It may be noted that in the pygidium from Tyers the marginal spines are less broad and hook-like than is normal for the subgenus.

Family ODONTOPLEURIDAE Burmeister

Genus *Leonaspis* Richter and Richter 1917

Leonaspis bispinosa sp. nov.

(Pl. XXI, fig. 1; Pl. XXXV, fig. 6-13; Fig. 17)

DIAGNOSIS: *Leonaspis* with one strong inwardly and upwardly directed spine mounted well down the labrigenal spine.

DESCRIPTION: Cranium with a convex occipital ring mounted on which is a comparatively small median tubercle; occipital furrow broad and smooth. Median glabellar lobe widening anteriorly, expanding to reach its maximum diameter at the end of the basal glabellar furrows, and with a rounded anterior margin. 2 pairs of longitudinally ovate lateral glabellar lobes, the anterior pair of which are the more tumid; separated from the median glabellar lobe by the deep basal glabellar furrows. The lower posterior pair are separated from the anterior pair by a lateral glabellar furrow. The well developed eye ridges arise opposite the point of maximum width of the median glabellar lobe and curve backwards apparently obliquely intersecting the facial suture. Frontal branch of facial suture convex outwards. Between the eye ridge and the facial suture is a triangular area of the fixed cheek, bearing a furrow which deepens anteriorly. There is a corresponding triangular area between the eye ridge and the glabella. Posterior branch of facial suture convex forwards, subparallel to the narrow posterior border, across which it curves just inside the genal angle. Palpebral region arched so as to overhang the posterior border. Anterior border short, rising anteriorly, bearing about 10 small spines just inside the straight transverse anterior margin. Surface with fine, closely spaced tubercles on the occipital ring, glabellar lobes and eye ridges. The area of the fixed cheek between the eye ridge and the glabella bears coarser, more distant tubercles, with one large tubercle immediately to each side of the occipital furrow.

Free cheeks triangular, convex, particularly in the eye region, with gently rounded lateral outline and a poorly defined lateral border which becomes wider posteriorly and merges with the broad base of the labrigenal spine. A series of somewhat blunt and flattened, occasionally curved, border spines is mounted along the outer margin of the free cheek. These are usually 12 in number, and gradually increase in size posteriorly, the third last in general being the longest as the last two tend to be reduced in size. A single stout upwardly and posteriorly directed spine is mounted on the inner edge of the labrigenal spine. Labrigenal spine long, flattened, tapering and bearing coarse, widely spaced tubercles on both surfaces. Upper surface of free cheek with low tubercles which become much more closely spaced around the eye. Eye almost stalked, with pyramidal upper surface; eye facets small, arranged in diagonal series.

Thoracic segments with well developed, strongly convex axial rings. Pleurae with a broad median ridge which is projected posteriorly as a long spine. Ornament of 2 tubercles on each side of the axial ring, and another pair on the plural ridges each side of the axial ring, but this appears to vary. Number of thoracic segments unknown.

Pygidium with 2 well separated, strongly convex axial rings. Pleural region with a low raised ridge running transversely from the first axial ring and swinging sharply to the posterior to one of the major marginal spines. Usually a pair of coarse tubercles is mounted on this pleural ridge, but otherwise the surface is irregularly tuberculate. 12 lateral border spines are present, the anterior 2 pairs of which are strongly reduced. The remainder, apart from the 2 major spines, extend approximately the same distance posteriorly, although the lateral spines are thinner.

TYPE AND FIGURED SPECIMENS: Holotype M.3483; M.3482, 4-6, Loc. 43, Boola Beds.

OCCURRENCE: Loc. 40 (rare), 43 (common), 47 (rare), Boola Beds.

REMARKS: This species clearly differs from the other Australian species of *Leonaspsis* such as *L. rattei* (Eth. and Mitch.), *L. parvissima* (E. and M.) and *L. hartleii* (Mitchell) in possessing the strong inwardly directed spine on the labrigenal spine. This feature also serves to distinguish *L. bispinosa* from overseas species.

Family CALYMENIDAE Burmeister

Genus *Gravicalymene* Shirley 1936

Gravicalymene angustior (Chapman)

(Pl. XXXV, fig. 16-17)

Calymene angustior Chapman 1915, p. 164-6, Pl. 15, fig. 8-10.

? *Calymene australis* Etheridge and Mitchell 1917, p. 481-6, Pl. 24, fig. 1-3, 6-7, ? 9; ? Pl. 27, fig. 1.

Calymene (*Gravicalymene*) ? *angustior* Chapman, Shirley 1938, p. 487, Pl. 44, fig. 17.

Gravicalymene angustior (Chapman) Gill 1942, p. 45; Gill 1945b, p. 176-9, Pl. 7, fig. 5, 10.

? *Gravicalymene australis* (Etheridge and Mitchell) Gill 1948, p. 69-71, Pl. 8, fig. 9-12.

DESCRIPTION: Cranidium about twice as wide as long, with a comparatively narrow tumid bell-shaped glabella, with 4 lateral glabellar lobes on each side, the anterior 2 of which are poorly defined. Occipital ring wide, well delineated by a deep occipital furrow. Pre-glabellar field wide with a well-defined anterior border.

Pygidium strongly convex, with a well defined axial region which tapers posteriorly. Axial rings well marked anteriorly, but fading posteriorly, apparently with 6 rings. Pleural regions with 5 'segments' the posterior of which is poorly defined; the 4 anterior segments bear furrows towards the margin.

FIGURED SPECIMENS: M.3478, 87, Loc. 47, Boola Beds.

OCCURRENCE: Loc. 43 (rare), 47 (occasional), 49 (rare), Boola Beds.

REMARKS: This form from the Boola Beds appears to be closest to *G. angustior* from the Yering Beds. Gill (1948) has considered that this species is separable from *G. australis*. I am not fully convinced of this, nor, for that matter, that this species and other closely related eastern Australian forms can be strictly placed in the genus *Gravicalymene*. The few specimens from Tyers, however, throw little light on these problems.

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Explanation of Plates

All figures unretouched. All numbers prefixed by 'M' refer to catalogue numbers in the Melbourne University Geology Department Fossil Collection, while those prefixed by 'T' refer to catalogue numbers in the Melbourne University Geology Department Fossil Thin Section and Slide Collection. L.S. and T.S. = longitudinal section and transverse section respectively.

PLATE XI

- Fig. 1-2—*Favosites gathlandicus* Lamarck. (1) L.S., T.713; (2) T.S., T.712—both from M.2888, Loc. 11. x 3.
- Fig. 3—*Favosites* sp. affn. *F. forbesi* Edwards and Haime. T.784 from M.2925, Loc. 19. x 3.
- Fig. 4-5—*Favosites forbesi* Edwards and Haime. (4) T.S., T.723; (5) L.S., T.724—both from M.2892, Loc. 27. x 5.
- Fig. 6-9—*Favosites goldfussi* d'Orbigny. (6) T.S., T.764; (7) L.S., T.765—both from M.2916, Loc. 19. x 5; (8) L.S., T.770 from M.2919, Loc. 23. x 10; (9) T.S., T.772 from M.2920, Loc. 5. x 10.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XII

All figures x 5.

- Fig. 1-2—*Favosites hilloc* sp. nov. (1) L.S., T.789; (2) T.S., T.790—both from holotype M.2927, Loc. 11, Limestone Phase, Coopers Creek Formation.
- Fig. 3-4—*Favosites eoetilis* sp. nov. (3) L.S., T.833; (4) T.S., T.834—both from holotype M.2949, Loc. 11, Limestone Phase, Coopers Creek Formation.
- Fig. 5-6—*Favosites ollant* Jones. (5) T.S., T. 822; (6) L.S., T.823—both from M.2944, Loc. 27, Limestone Phase, Coopers Creek Formation.
- Fig. 7-8—*Favosites moanbiensis* Etheridge. (7) T.S., T.798; (8) L.S., T.800—both from M.2932, Loc. 48, Boola Beds.

PLATE XIII
All figures x 5.

- Fig. 1-2—*Favosites squamuliferus* Etheridge forma *bryani* Jones. (1) T.S., T.891 from M.2973, Loc. 11; (2) L.S., T.917 from M.2982, Loc. 11, Limestone Phase, Coopers Creek Formation.
- Fig. 3-4—*Favosites* sp. (3) T.S., T.1055; (4) L.S., T.1056—both from M.3009, Loc. 27, Limestone Phase, Coopers Creek Formation.
- Fig. 5-6—*Favosites squamuliferus* Etheridge (?). (5) T.S., T.1043; (6) L.S., T.1044—both from M.3007, Loc. 11, Limestone Phase, Coopers Creek Formation. Note the abundant squamulae.
- Fig. 7—'*Favosites* (*Emmonsia*) *spinigero*' of Chapman (*non* Hall) T.1203 *ex* Chapman Collection. Deep Creek Limestone.
- Fig. 8—'*Emmonsia*' sp. affin. *E. fusta* Greene. L.S., T.1052 from M.3008, Loc. 3, Limestone Phase, Coopers Creek Formation. Corallum attached to a erinoid stem ossicle.

PLATE XIV
All figures x 10.

- Fig. 1-3—*Favosites hillae* sp. nov. (1) T.S., T.791; (2) T.S., T.790—both from holotype M.2927. Sections illustrating variation in development of septal apparatus and wall thickness. (3) L.S., T.789 from holotype M.2927, Loc. 11.
- Fig. 4-6—*Favosites coactilis* sp. nov. (4) T.S., T.834 from holotype M.2949; (5) T.S., T.835 from paratype M.2950. Section of a subdigitate corallum showing the thin-walled axial portion (cf. fig. 4). (6) L.S., T.833 from holotype M.2949. All specimens from Loc. 11.
- Fig. 7-8—*Favosites maeilentus* sp. nov. (7) T.S., T.850; (8) L.S., T.852—both from holotype M.2956, Loc. 11.
- All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XV

- Fig. 1-2—*Favosites* sp. cf. *F. inosculans* Nicholson. (1) T.S., T.826; (2) L.S., T.827—both from M.2947, Loc. 19. x 10.
- Fig. 3-4—*Favosites squamuliferus* Etheridge forma *australis* Chapman. (3) T.S., T.938; (4) L.S., T.937—both from M.2989, Loc. 11. Specimen showing small corallite diameter. x 10.
- Fig. 5—*Alveolites* sp. affin. *A. taenioformis* Schlüter L.S., T.917 from M.2982, Loc. 11, Limestone Phase, Coopers Creek Formation. Specimen encrusted by a corallum of *Favosites squamuliferus* forma *bryani*. x 5.
- Fig. 6—*Alveolites* sp. T.1062, Loc. 27. x 5.
- All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XVI
All figures x 5.

- Fig. 1, 5—*Notolophyllum callidum* sp. nov. (1) T.1074 from M.3011, holotype, Loc. 20; (5) T.830 from M.2984, Loc. 15—specimen showing sub-pyriform corallum.
- Fig. 2-4—*Thomnopora boloniensis* (Gosselet). (2) L.S., T.1067; (3) Tangential section T.1068—both from M.3010, Loc. 11; (4) T.S., T.1073, Loc. 51, Boola Beds.
- Fig. 6—*Thomnopora alterivalis* (Chapman). L.S., T.1081, Loc. 27.
- All specimens from Limestone Phase, Coopers Creek Formation, unless otherwise stated.

PLATE XVII

- Fig. 1-4—*Coenites* (*Coenites*) *planifolium* sp. nov. (1) Section cut parallel to the surface of corallum, T.1085, holotype; (2) T.S., T.1091; (3) T.S., T.1088, holotype; (4) T.S., T.1090. All specimens from Loc. 48, Boola Beds. x 5.
- Fig. 5-6—*Coenites* (*Cladopora*) *faliato* (Jones). (5) L.S., T.1100; (6) Section parallel to surface of corallum in part T.S. and in part L.S., T.1095. In the middle and upper part of the slide a bryozoan can be seen between two 'branches' of the *Coenites* corallum. Both specimens from Loc. 11, Limestone Phase, Coopers Creek Formation. x 5.
- Fig. 7—*Heliolites daintreei* Nicholson and Etheridge. T.S., T.1131, Loc. 11, Limestone Phase, Coopers Creek Formation. x 10.

PLATE XVIII

Fig. 1, 3-7—*Coenites (Clodopora) gippslandica* (Chapman). (1) T.S., T.1114, Loc. 48, Boola Beds; (3) T.S., T.1109; (4) L.S., T.1110—both from M.3014, Loc. 11, Limestone Phase, Coopers Creek Formation, a large corallum with the thickness of the walls in the axial region accentuated by a layer of secondary calcite; (5) Tangential section T.1112, Loc. 48, Boola Beds. Section showing the shape and distribution of the calices at the surface of the corallum; (6) L.S., T.1113; (7) L.S., T.1111—both from Loc. 48, Boola Beds. Illustrated slides chosen to show the variation within the species. $\times 10$.

Fig. 2—*Coenites (Clodopora) foliata* (Jones). T.S., T.1099, Loc. 19, Limestone Phase, Coopers Creek Formation. $\times 5$.

PLATE XIX

All figures $\times 10$.

Fig. 1-4—*Heliolites dointeei* Nicholson and Etheridge. (1) T.S., T.1134; (2) L.S., T.1133 from same specimen, Loc. 20; (3) T.S., T.1135; (4) L.S., T.1136 from same specimen, Loc. 19.

Fig. 5-6—*Plosmopora gippslandica* (Chapman). (5) T.S., T.1057; (6) L.S., T.1056—both from M.3017, Loc. 5.

All specimens from the Limestone Phase, Coopers Creek Formation.

PLATE XX

Fig. 1-2—*Fosstopora quintoria* sp. nov. (1) T.S., T.1124; (2) L.S., T.1125—both from holotype M.3015, Loc. 11. $\times 10$.

Fig. 3-4—*Roemeria thomii* (Chapman). (3) T.S., T.1161; (4) L.S., T.1162—both from M.3013, Loc. 22. $\times 3$ approx.

Fig. 5-6—*Aulopora* sp. aff. *A. emergens* Quenstedt. (5) T.S., T.1166; (6) L.S., T.1167—both from same corallum, Loc. 11. $\times 10$.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XXI

All figures $\times 1$ unless otherwise stated.

Fig. 1, 6—*Pleurodictyum megostoma* McCoy. (1) M.3012, Loc. 43, Boola Beds, together with pygidium of *Leonaspis bispinosa* sp. nov.; (6) M.3013, Loc. 36, Conglomerate Phase, Coopers Creek Formation. Specimen showing small corallite diameter. $\times 2$.

Fig. 2—*Coenites (Coenites) planifolium* sp. nov. M.3044, Loc. 7, Boola Beds; mould of a corallum.

Fig. 3—*Pseudomplexus princeps* (Etheridge) var. *confertus* var. nov. Holotype. M.3024, Loc. 19, Limestone Phase, Coopers Creek Formation; polished transverse section.

Fig. 4—*Favosites moonbiensis* Etheridge. M.2940. Loc. 47, Boola Beds; mould of a corallum.

Fig. 5, 8, 9—*Favosites forbesi* Edwards and Haime. (5) M.2909, Loc. 49, Boola Beds, mould of a small corallum; (8) M.2931, Loc. 47, Boola Beds; mould of specimen enlarged to show irregularly arranged mural pores and septal spines; lower part of figure shows the sole specimen of *Favosites squamuliferus* forma *nitidus* collected from the Boola Beds. $\times 5$. (9) M.2926, Loc. 11, Limestone Phase, Coopers Creek Formation; weathered corallum exposed on a limestone slab.

Fig. 7—*Rhizophyllum* (?) sp. M.3042, Loc. 48, Boola Beds.

PLATE XXII

All figures $\times 2$.

Fig. 1-8—*Syringaxon (Soucrophyllum) pocillum* subgenus et sp. nov. (1-6) Serial T.S. from paratype with distance between sections given in mm; (1) T.1193; (2) T.1194—5.4; (3) T.1195—2.4; (4) T.1196—2.6; (5) T.1197—2.5; (6) T.1198—2.5; (7) T.1191, Tangential section showing dissepiments in the interseptal loculi; (8) T.1190, L.S.—both from holotype, M.3021. All specimens from Loc. 50, Boola Beds.

Fig. 9—*Syringaxon (Syringaxon)* sp. T.S., T.1176, Loc. 50, Boola Beds.

Fig. 10—*Springaxon (Borrandephyllum)* sp. T.1184, Loc. 15, Limestone Phase, Coopers Creek Formation.

Fig. 11-12—*Pseudomplexus princeps* (Etheridge) var. *confertus* var. nov. (11) L.S., T.1514; (12) T.S., T.1513—both from M.3024, holotype, Loc. 19, Limestone Phase, Coopers Creek Formation.

Fig. 13—*Pseudamplexus princeps* (Etheridge). L.S., T.1508, from M.3023, Loc. 19, Limestone Phase, Coopers Creek Formation.

Fig. 14—*Phillipsostrea maculosa* Hill. T.S., T.1519 from M.3026, Loc. 20, Limestone Phase, Coopers Creek Formation.

PLATE XXIII

All figures $\times 2$.

Fig. 1, 5—*Heliophyllum* sp. affin. *H. pinguiseptatum* Hill. (1) L.S., T. 1518; (5) T.S., T.1517 both from M.3025, Loc. 20.

Fig. 2—*Thamnophyllum reclinatum* Hill. T.S., T.1546, Loc. 20.

Fig. 3-4—*Micthophyllum* sp. affin. *M. cresswelli* (Chapman). (3) T.S., T.1543; (4) L.S., T.1544—both from M.3031, Loc. 17.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XXIV

All figures $\times 2$.

Fig. 1, 7—*Disphyllum incongruum* sp. nov. (1) L.S., T.1575; (7) T.S., T.1574—both from holotype M.3034, Loc. 21.

Fig. 2-3—*Disphyllum* (?) sp. (2) T.S., T.1542; (3) L.S., T.1541—from same specimen, Loc. 11.

Fig. 4, 8, 9—*Hexagonaria approximans* (Chapman). (4) L.S., T.1524; (9) T.S., T.1525—both from M.3027, specimen showing carinate septa; (8) T.S., T.1527 from M.3028. All from Loc. 11.

Fig. 5, 10—*Disphyllum cognatum* sp. nov. (5) L.S., T.1537; (10) T.S., T.1536—both from holotype, M.3030, Loc. 19.

Fig. 6—*Phillipsostrea speciosa* Chapman. T.1520, Loc. 15.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XXV

Fig. 1-2, 7-10—*Thamnophyllum reclinatum* Hill. (1) T.S., T.1545 from M.3032, Loc. 15; (2) T.S., T.1550; (8) L.S., T.1551—both from same specimen showing corallites with wide peripheral zone of septal dilation, Loc. 20; (7) L.S., T.1547, Loc. 20; (9) T.S., T.1548; (10) L.S., T.1549—both from Loc. 15. All $\times 4$ approx.

Fig. 3-4—*Tipheophyllum ops* sp. nov. (3) T.S., T.1580; (4) L.S., T.1579—both from holotype M.3035, Loc. 15. $\times 2$.

Fig. 5-6—*Tipheophyllum* sp. (5) L.S., T.1588; (6) T.S., T.1589—both from Loc. 15. $\times 2$.

Fig. 11-12—*Trapezophyllum elegantulum* (Dun) (11) T.S., T.1573; (12) L.S., T.1572—both from M.3033, Loc. 7. $\times 2$.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XXVI

All figures $\times 2$.

Fig. 1, 6—*Xystriphyllum mitchelli* (Etheridge). (1) L.S., T.1535; (6) T.S., T.1534—both from M.3029, Loc. 11.

Fig. 2-3—*Acanthophyllum acquiseptatum* Hill. (2) L.S., T.1593; (3) T.S., T.1592—both from same specimen, Loc. 3.

Fig. 4-5—*Tabulophyllum* (?) *meridionale* sp. nov. (4) T.S., T.1590; (5) L.S., T.1591—both from holotype, M.3036, Loc. 15.

Fig. 7-8—*Acanthophyllum sweeti* Etheridge. (7) T.S., T.1606; (8) L.S., T.1607—from the same specimen, Loc. 15.

Fig. 9-10—*Acanthophyllum mansfieldense* (Dun)? (9) T.S., T.1597; (10) L.S., T.1596—both from Loc. 3.

Fig. 11-12—*Acanthophyllum mansfieldense* (Dun). (11) L.S., T.1602; (12) T.S., T.1601—both from M.3038, Loc. 20.

All specimens from Limestone Phase, Coopers Creek Formation.

PLATE XXVII

Fig. 1-2—*Acanthophyllum elermonstensis* (Etheridge). (1) T.S., T.1599; (2) L.S., T.1600—both from M.3037, Loc. 20, Limestone Phase, Coopers Creek Formation. $\times 2$.

PLATE XXVIII
All figures x 2.

- Fig. 1-2—*Cystiphyllum* sp. affin. '*C. australiae* Etheridge. (1) T.S., T.1672; (2) L.S., T.1673—
—from the same specimen, Loc. 13, Limestone Phase, Coopers Creek Formation
Fig. 3, 10—*Tryplasma* sp. A. (3) T.S., T.1646, Loc. 15; (10) L.S., T.1647, Loc. 22—both from
Limestone Phase, Coopers Creek Formation.
Fig. 4-5—*Tryplasma calummare* Etheridge. (4) L.S., T.1640; (5) T.S., T.1639—
—from the same specimen, Loc. 5, Limestone Phase, Coopers Creek Formation.
Fig. 6-7—*Lyriellasma subcaespitosum* (Chapman) S.S. (6) T.S., T.1631, showing peripheral
increase with a circlet of young corallites arising from the widely lonsdaleoid dissepiments
of the parent corallites, Lilydale Limestone; (7) L.S., T.1628, Lilydale Limestone.
Fig. 8-9—*Dahmaphyllum pridianum* sp. nov. (8) L.S., T.1614; (9) T.S., T.1613—both from
holotype M.3039, Loc. 13, Limestone Phase, Coopers Creek Formation.
Fig. 11-12—*Lyriellasma subcaespitosum praeursor* subsp. nov. (11) L.S., T.1620; (1) T.S.,
T.1619—both from holotype M.3040, Loc. 15, Limestone Phase, Coopers Creek Formation.
Fig. 13—*Micrasplasma* sp. cf. *M. devanica* Soshkina. L.S., T.1670, Loc. 50, Boola Beds.

PLATE XXIX
All figures x 2 unless otherwise stated.

- Fig. 1, 3—*Tryplasma wellingtonensis* Etheridge. (1) T.S., T.1643, Loc. 3; (3) T.S., T.1644,
Loc. 21—both from Limestone Phase, Coopers Creek Formation.
Fig. 2, 6—*Tryplasma etheridgei* sp. nov. and *Micrasplasma* sp. cf. *M. devanica* Soshkina. (2)
L.S., T.1635; (6) T.S., T.1636—Loc. 50, Boola Beds.
Fig. 4, 8—*Tryplasma etheridgei* sp. nov. (4) L.S., T.1633; (8) T.S., T.1634—holotype, Loc. 50,
Boola Beds. x 5.
Fig. 5, 7—*Tryplasma* sp. B. (5) L.S., T.1649; (7) T.S., T.1648—Loc. 48, Boola Beds.
Fig. 9-10—*Nuculites* sp. (9) M.3397A, internal mould of left valve; (10) M.3397B, counter-
part, Loc. 43, Boola Beds. x 5 approx.
Fig. 11, 13-15, 17—*Ctenadonta* (*Praectenodonta*) *raricostae* (Chapman) subgen. nov. (11) En-
largement of dentition beneath the umbos of specimen in fig. 17. x 5 approx. (13)
Internal mould of right valve P. 17419, Syme's Homestead; (14) Dorsal view of
same; (15) Counterpart P. 17420; (17) Both valves showing the uninterrupted row
of taxodont teeth beneath the umbos, P. 17418, Killara Tunnel. x 2.
Fig. 12—*Actinapteria* sp. Latex impression of external mould of left valve M.3414, Loc. 36,
Conglomerate Phase, Coopers Creek Formation. x 5 approx.
Fig. 16—*C. (Praectenodonta) victoriae* (Chapman) subgen. nov. External mould M.3398, Loc.
43, Boola Beds. x 2.
Fig. 18—*Conocardium costatum* (Cresswell). Internal mould of both valves, M.3399, Loc. 36,
Conglomerate Phase, Coopers Creek Formation. x 2.
Fig. 19—*Straparalus* sp. M.3412, Loc. 43, Boola Beds. x 2.

PLATE XXX
All figures x 2.

- Fig. 1-6—*Dolerorthis persculpta* sp. nov. (1) Internal mould of dorsal valve M.3414A; (5)
Counterpart M.3414B, from Loc. 48, Boola Beds; (2) External mould of holotype
M.3416B, a dorsal valve, Loc. 47, Boola Beds; (3) Holotype M.3416A; (4) Latex
impression of holotype M.3416A; (6) Internal mould of ventral valve, M.3417, Loc.
47, Boola Beds.
Fig. 7-11—*Onniella* (?) *tyersensis* sp. nov. (7) External mould of a large ventral valve
M.3421B; (8) Counterpart M.3421A; (9) Internal mould of dorsal valve M.3422;
(10) M.3423; (11) Holotype M.3424, dorsal valve. All from Loc. 43, Boola Beds.
Fig. 12-19—*Tyersella typica* gen. et sp. nov. (12) Posterior view of a dorsal valve showing the
high socket ridges, M.3425; (13) Internal mould of dorsal valve, M.3426A, holotype;
(14) Latex impression of holotype, M.3426A; (15) Counterpart, M.3426B; (16)
Internal mould of a small dorsal valve M.3427; (17) Internal mould of ventral valve
M.3428; (18) Oblique view of an internal mould of the ventral muscle area, showing
the pedicle callist M.3429; (19) Dorsal and ventral valves, M.3427. All specimens
from Loc. 36, Conglomerate Phase, Coopers Creek Formation.

- Fig. 20-24—*Resserella impensa* sp. nov. (20) External mould of dorsal valve of holotype, M.3430B; (21) Dorsal view of holotype M.3430A, internal mould of both valves; (22) Ventral view of same, Loc. 49, Boola Beds; (23) Internal mould of ventral valve M.3431; (24) Internal mould of ventral valve M.3432, both from Loc. 36, Conglomerate Phase, Coopers Creek Formation.

PLATE XXXI

All figures $\times 2$ unless otherwise stated.

- Fig. 1-2—*Schizophoria* sp. indet. (1) Internal mould of dorsal valve, M.3433, Loc. 47, Boola Beds; (2) Internal mould of a fragmentary ventral valve, M.3434, Loc. 49, Boola Beds.
 Fig. 3-6—*Isorthis festiva* sp. nov. (3) Internal mould of dorsal valve, M.3435, Loc. 49, Boola Beds; (4) Ventral view of a fragmentary internal mould of both valves, M.3436A, holotype; (5) External mould of dorsal valve of same, M.3436B, Loc. 47, Boola Beds; (6) Internal mould of dorsal valve, M.3437, Loc. 49, Boola Beds.
 Fig. 7-8—*Gypidula victoriae* Chapman. (7) Internal mould of ventral valve, M.3438A; (8) Counterpart of same, M.3438B.
 Fig. 9-10—*Notanophia australis* (Gill). (9) External mould of ventral valve, M.3439B; (10) Counterpart of same, M.3439A, Loc. 47, Boola Beds. $\times 5$.
 Fig. 11-17—*Notanophia* sp. (11) Internal mould of dorsal valve together with an external mould of *Cladopora* (*Cladopora*) *gippslandica* (Chapman), M.3440, Loc. 36, Conglomerate Phase, Coopers Creek Formation; (12) Two ventral interiors together with an external mould of portion of a valve of *Lissatrypa lenticulata* sp. nov. M.3441; (13) Fragmentary internal moulds of a dorsal and ventral valve, M.3442. $\times 5$; (14) Internal mould of dorsal valve, M.3443. $\times 5$; (15) Internal mould of ventral valve, M.3444. $\times 5$; (16) External mould of dorsal valve. M.3445. $\times 5$; (17) Internal mould of ventral valve, M.3441. $\times 5$.
 Fig. 18-19—*Plectodonta bipartita* (Chapman). (18) Internal mould of a small dorsal valve together with a number of external moulds, M.3446, $\times 5$; (19) Internal mould of ventral valve, M.3447. $\times 5$.

All specimens from Loc. 43, Boola Beds, unless otherwise stated.

PLATE XXXII

Fig. 1-6, $\times 2$; 7-9, $\times 5$.

- Fig. 1—*Leptostrophia* sp. affn. *affinalata* (Gill). Internal mould of ventral valve, M.3448, Loc. 47, Boola Beds.
 Fig. 2-3—*Leptostrophia* sp. cf. *L. explanata* (Sowerby). (2) External mould of ventral valve, M.3449B; (3) Latex impression of counterpart M.3449A, Loc. 36, Conglomerate Phase, Coopers Creek Formation.
 Fig. 4-5—*Strophonella gippslandica* sp. nov. (4) Latex impression of holotype, M.3450, internal mould of ventral valve; (5) External mould of ventral valve, M.3451, both from Loc. 47, Boola Beds.
 Fig. 6—*Megastrophia* (?) sp. Ventral valve, M.3452, Loc. 11, Limestone Phase, Coopers Creek Formation.
 Fig. 7-9—*Chonetes cresswelli* Chapman. (7) Internal mould of ventral valve, M.3453; (8) The same, M.3454; (9) The same, M.3455. All from Loc. 43, Boola Beds.

PLATE XXXIII

All figures $\times 2$.

- Fig. 1-3—*Ucinulus* (?) sp. (1) Dorsal; (2) Anterior; (3) Ventral views of M.3456, Loc. 15, Limestone Phase, Coopers Creek Formation.
 Fig. 4-10—*Atrypa* sp. cf. *A. reticularis* (Linnaeus). (4) Ventral; (5) Dorsal; (6) Posterior; (7) Anterior views of M.3457, Loc. 48, Boola Beds; (8) Internal mould of dorsal valve, M.3458, Loc. 48, Boola Beds; (9) Internal mould of ventral valve, M.3433, Loc. 47, Boola Beds; (10) External mould of ventral valve of a specimen with closely spaced ribs, M.3459, Loc. 47, Boola Beds.
 Fig. 11—(?) *Leptostrophia* sp. affn. *affinalata* (Gill). Latex impression of internal mould of dorsal valve, M.3460, Loc. 43, Boola Beds.
 Fig. 12-13—*Notoleptaena otophora* Gill. (12) Internal mould of ventral valve, M.3461A; (13) Counterpart, M.3461B, Loc. 47, Boola Beds.
 Fig. 14-15—*Maoristrophia* sp. (14) Internal mould of ventral valve, M.3462A; (15) Counterpart, M.3462B, Loc. 36, Conglomerate Phase, Coopers Creek Formation.

PLATE XXXIV

All figures x 2, except fig. 3, x 5.

- Fig. 1-3—*Atrypa fimbriata* Chapman. (1) External mould of ventral valve together with an internal mould of the pygidium of *Cheirurus* (*Crotalocephalus*) *silverdalensis* Etheridge and Mitchell and an external mould of *Cypricardina* sp. M.3463A; (2) Internal mould of ventral valve M.3463B; (3) Enlargement of portion of fig. 1 showing the surface ornaments of both forms, Loc. 47, Boola Beds.
- Fig. 4, 17-21—*Lissatrypa lenticulata* sp. nov. (4) Posterior view of both valves, M.3464; (17) Internal mould of ventral valve, M.3465; (18) Internal mould of ventral valve M.3466; (19) Internal mould of ventral valve, M.3397; (20) Internal mould of dorsal valve, M.3467, holotype; (21) Internal mould of dorsal valve, M.3468. All from Loc. 43, Boola Beds.
- Fig. 5-9—*Plectatrypa australis* sp. nov. (5) Internal mould of both valves, ventral view, M.3469, Loc. 48, Boola Beds; (6) External mould of ventral valve, M.3470, Loc. 47, Boola Beds; (7) Ventral; (8) Dorsal; (9) Anterior views of holotype, M.3471, Loc. 48, Boola Beds.
- Fig. 10-13, 22—*Delthyris* (*Howellella*) *scabra* sp. nov. (10) Ventral; (11) Dorsal; (12) Lateral; (13) Posterior views of holotype, M.3472A, internal mould of both valves, Loc. 49, Boola Beds; (22) External mould of dorsal valve, M.3473, Loc. 47, Boola Beds.
- Fig. 14-16—*Eospirifer* sp. aff. *E. togatus* (Barrande). (14) Ventral valve, M.3474, Loc. 48, Boola Beds; (15) Internal mould of ventral valve, M.3475, Loc. 49, Boola Beds; (16) Internal mould of a large ventral valve, M.3476, Loc. 48, Boola Beds.

PLATE XXXV

All figures x 2 unless otherwise stated.

- Fig. 1—*Nucleospira* sp. Internal mould of ventral valve together with internal mould of hyperstome of *Cheirurus* (*Crotalocephalus*) *silverdalensis* Etheridge and Mitchell and an internal mould of a ventral valve of *Plectodonta bipartita* (Chapman), M.3477A, Loc. 43, Boola Beds.
- Fig. 2, 14-15—*Cheirurus* (*Crotalocephalus*) *silverdalensis* Etheridge and Mitchell. (2) External mould of hyperstome, counterpart of fig. 1, M.3477B; (14) Latex impression of external mould of a fragmentary glabella, M.3477; (15) Latex impression of another external mould of a glabella M.3479, all from Loc. 43, Boola Beds.
- Fig. 3—*Meristella* sp. Internal mould of ventral valve M.3488, Loc. 43, Boola Beds. x 5.
- Fig. 4—Internal mould of portion of an indeterminate cheirurid thorax, M.3480, Loc. 47, Boola Beds.
- Fig. 5—*Cheirurus* (*Cheirurus*) sp. Cranidium, M.3481, Loc. 55, Boola Beds.
- Fig. 6-13—*Leonaspis bispinosa* sp. nov. (6) Lateral view of internal mould of free cheek, showing eye, M.3482; (7) Latex impression of holotype, a cranidium, M.3483B; (8) Holotype, M.3483B; (9) Internal mould of holotype, M.3483A; (10) Internal mould of pygidium, M.3484; (11, 12) Lateral and ventral views of a latex impression of an external mould of the free cheek, M.3485; (13) Latex impression showing the underside of the free cheek, from M.2486. All specimens from Loc. 43, Boola Beds.
- Fig. 16-17—*Gravicalymene angustior* (Chapman). (16) Internal mould of cranidium, M.3487; (17) Internal mould of pygidium, M.3478, both from Loc. 47, Boola Beds.
- Fig. 18—*Delthyris* (*Howellella*) *scabra* sp. nov. External mould of dorsal valve showing the ornament, M.3462, Loc. 36, Conglomerate Phase, Coopers Creek Formation.

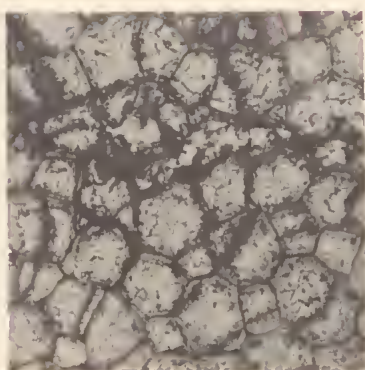
Addendum

Throughout the body of the text of this paper, as elsewhere (Philip 1960), the Boola Beds are taken as being of upper Ludlow age and the Coopers Creek Formation is thought to be early Lower Devonian.

The Silurian age of the Boola Beds was established on the brachiopods of the fauna. Particular emphasis was placed on the occurrence of the genera *Dolerorthis*, *Plectatrypa*, *Resserella* and *Lissatrypa* (the species of *Onniella* should only questionably be referred to that genus), with such other genera as *Plectodonta*, *Howellella*,



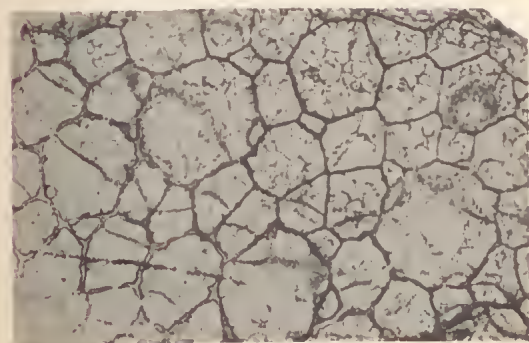
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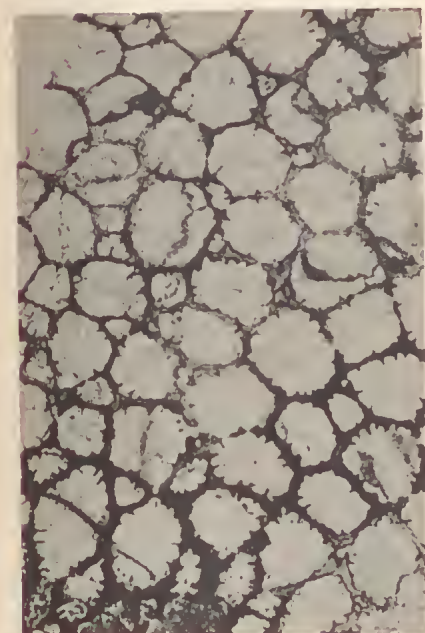
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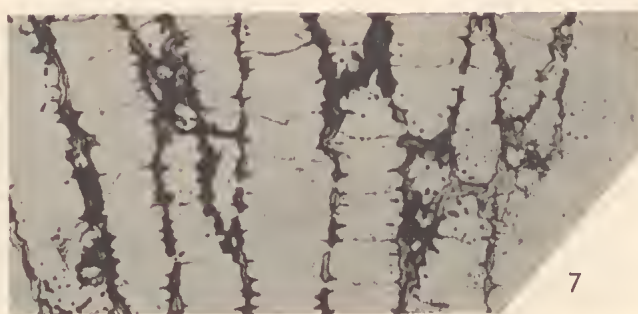
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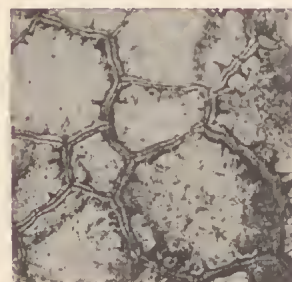
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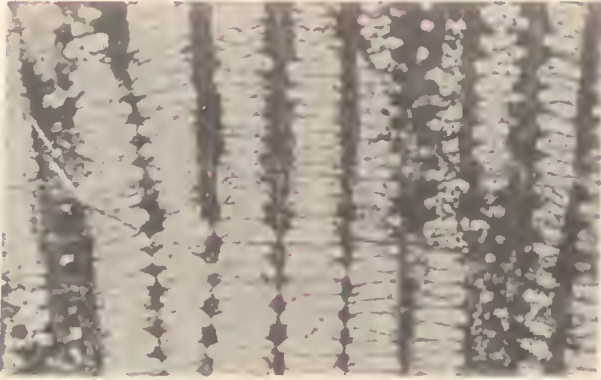
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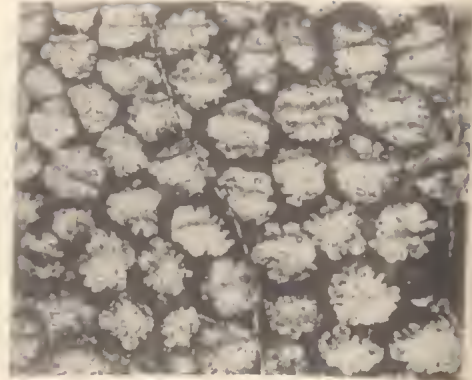
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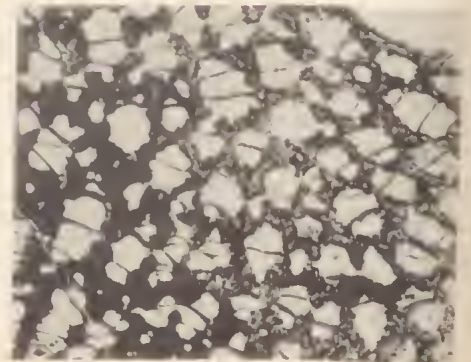
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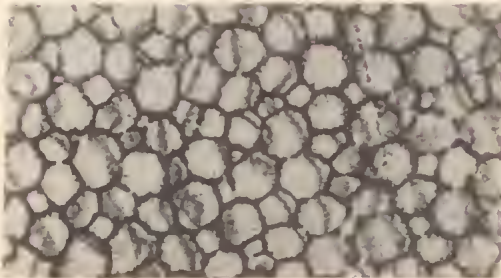
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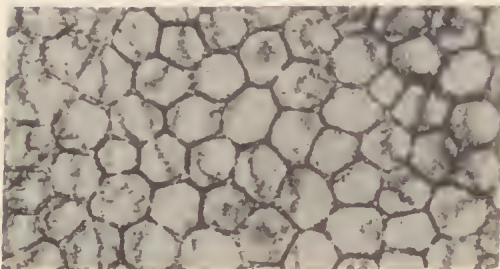
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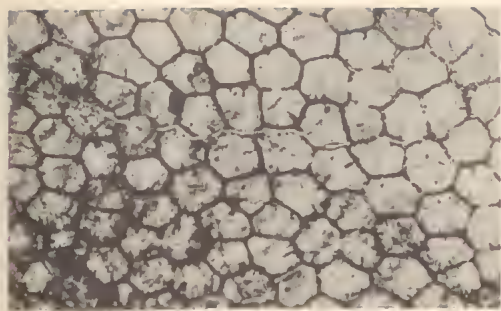
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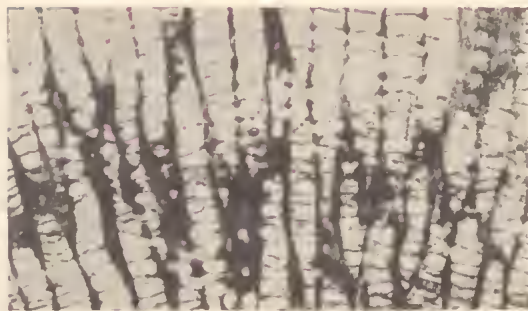
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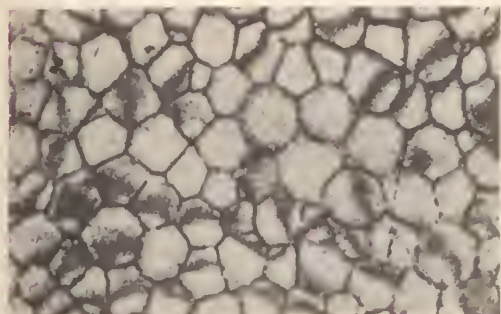
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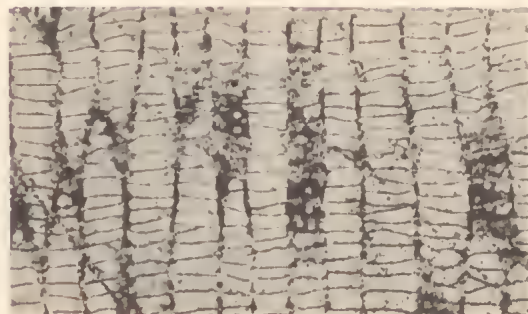
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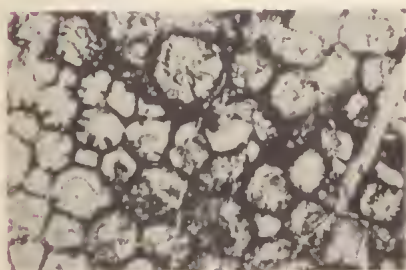
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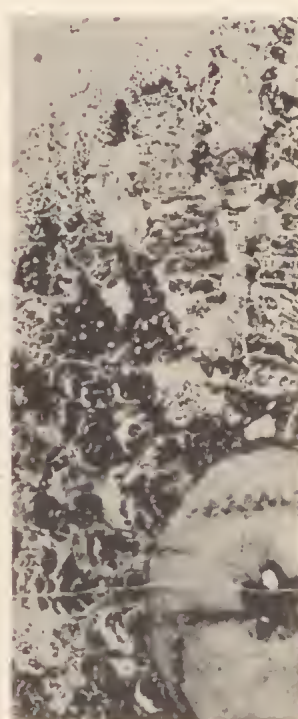
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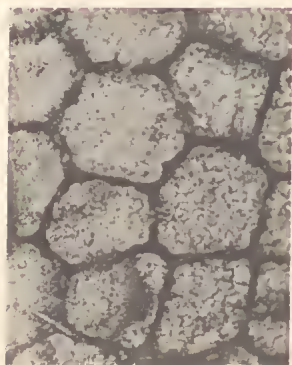
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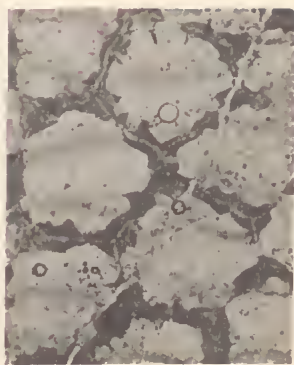
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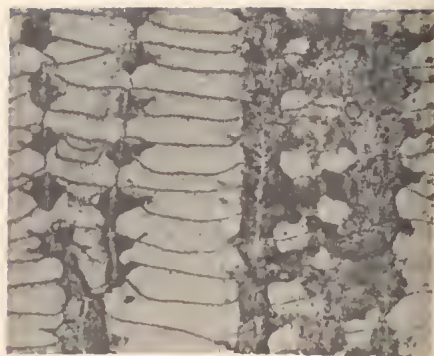
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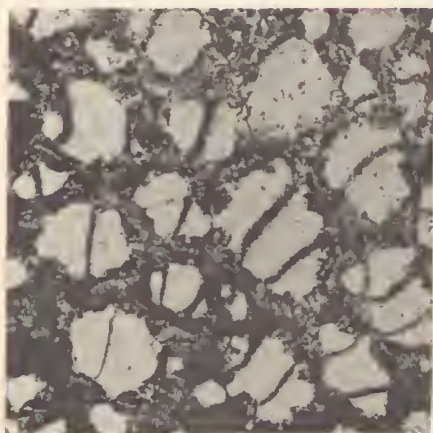
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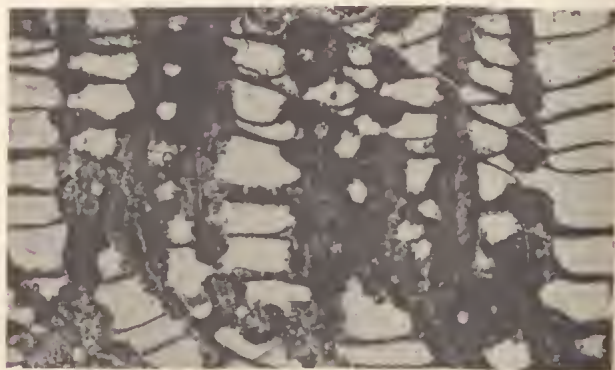
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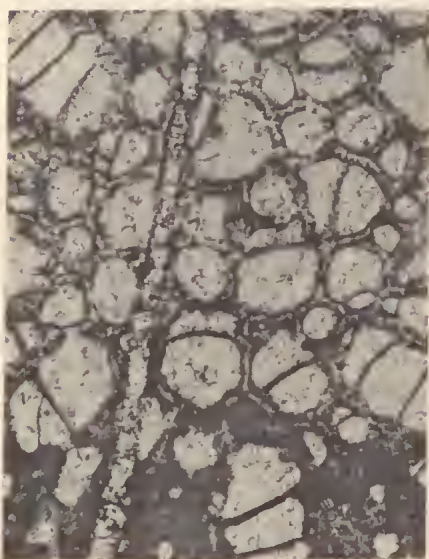
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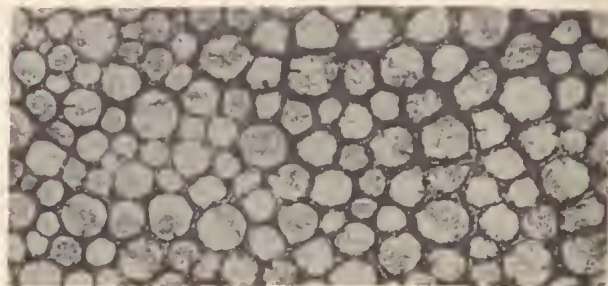
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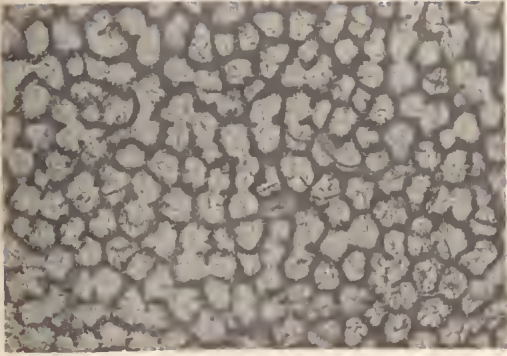
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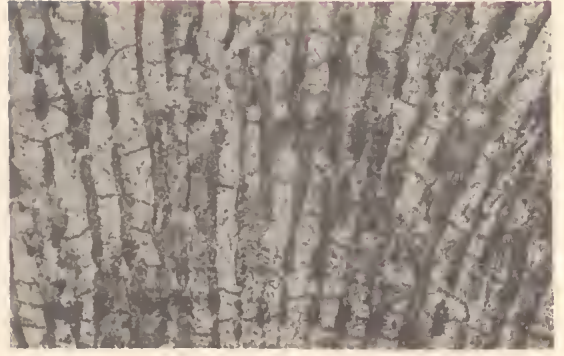
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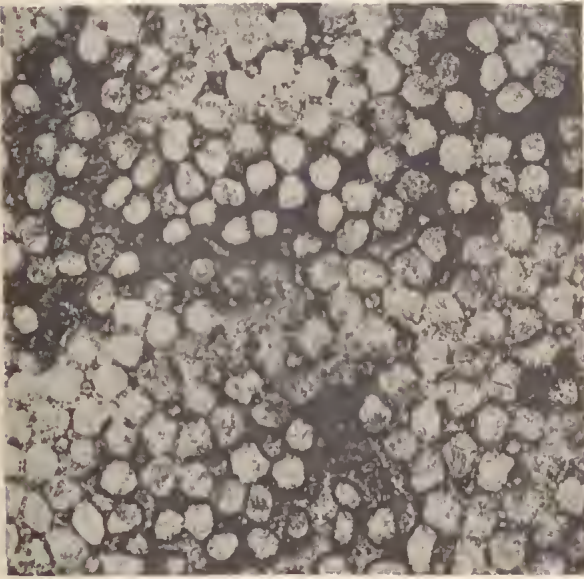
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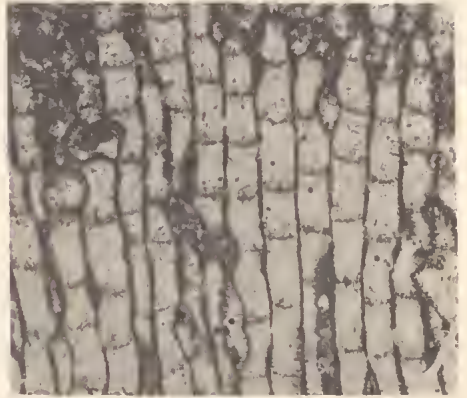
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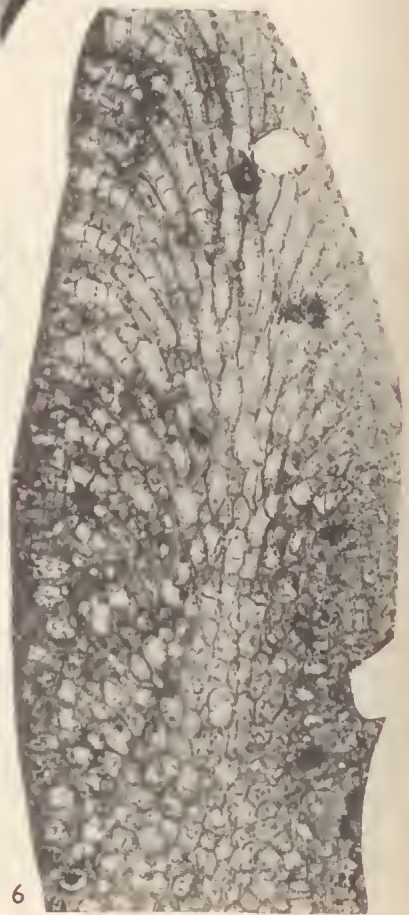
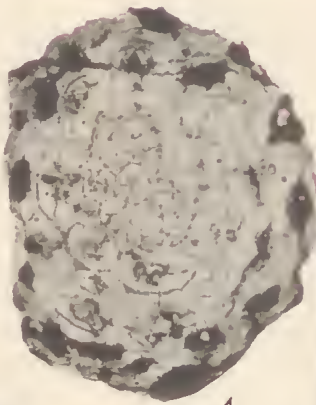
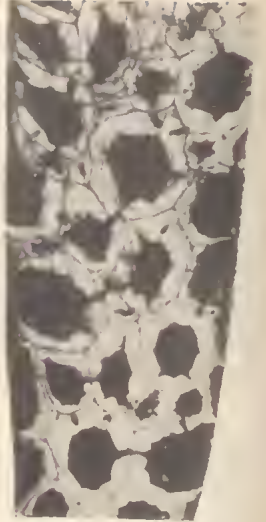
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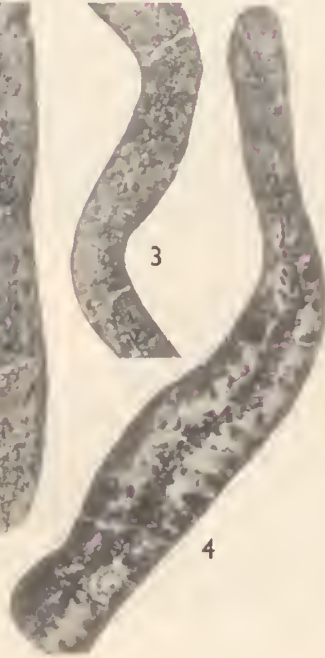
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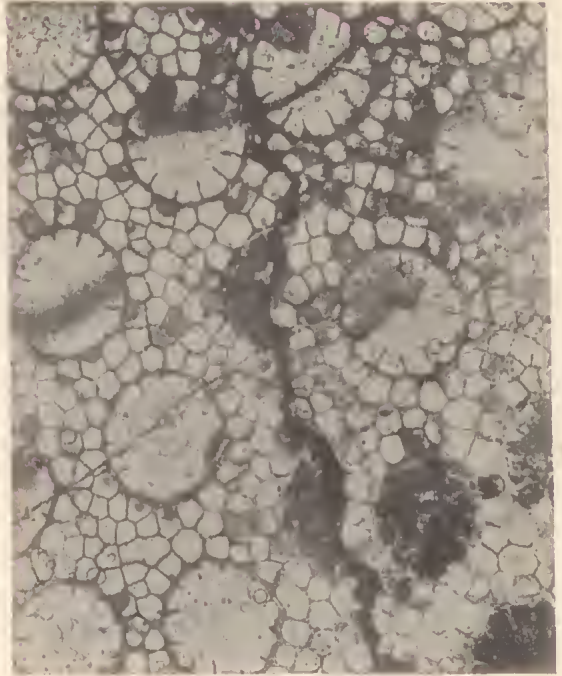
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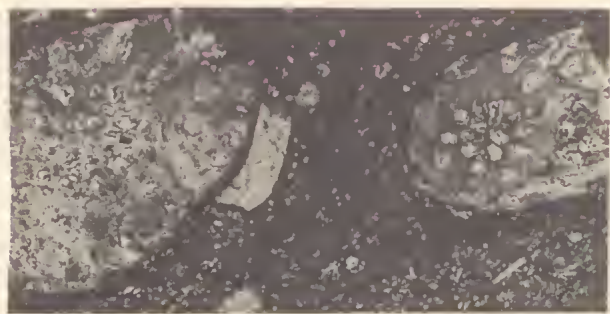
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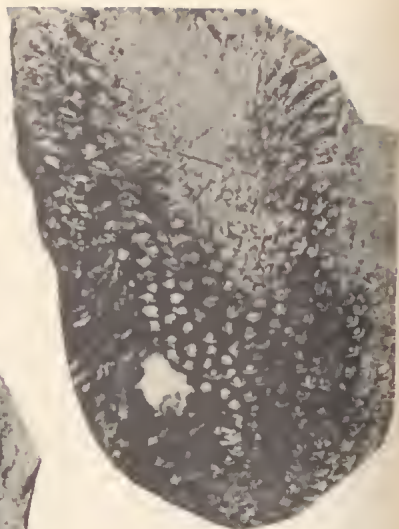
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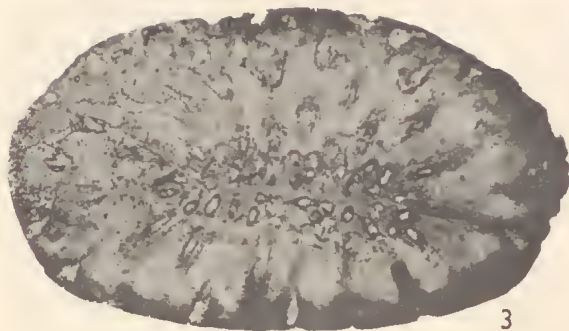
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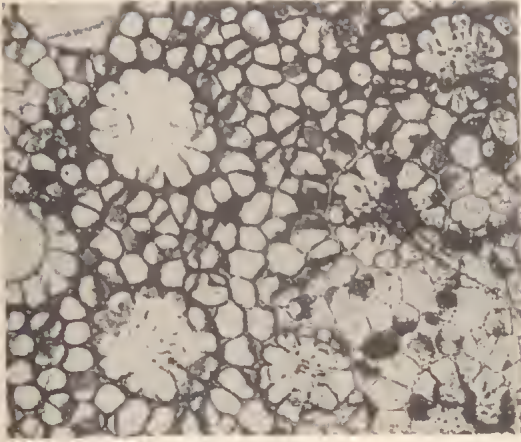
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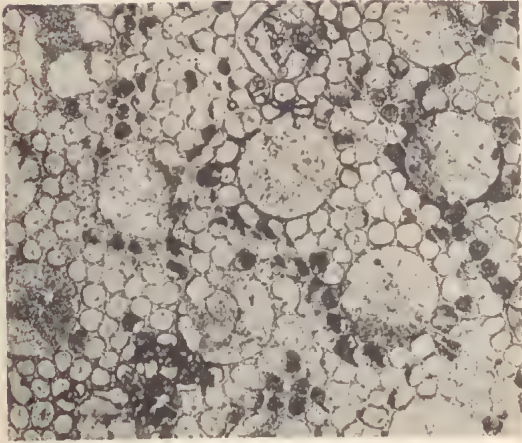
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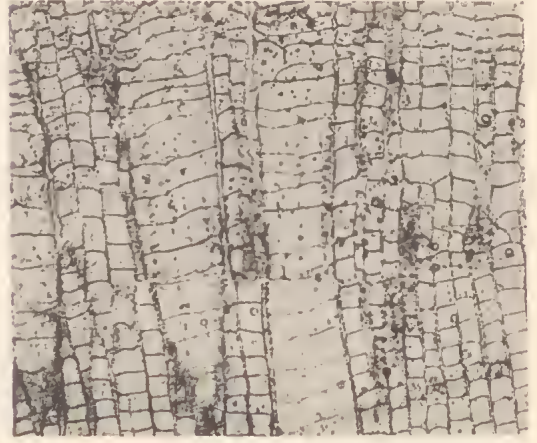
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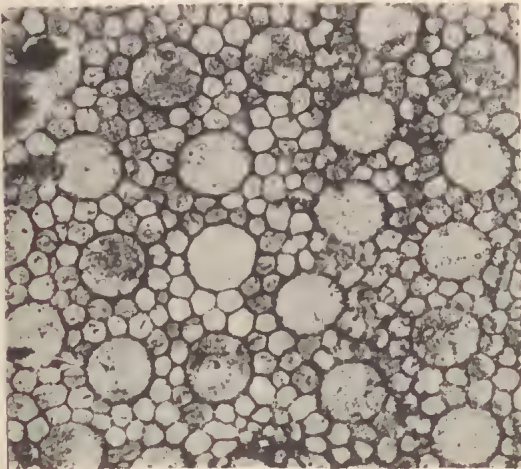
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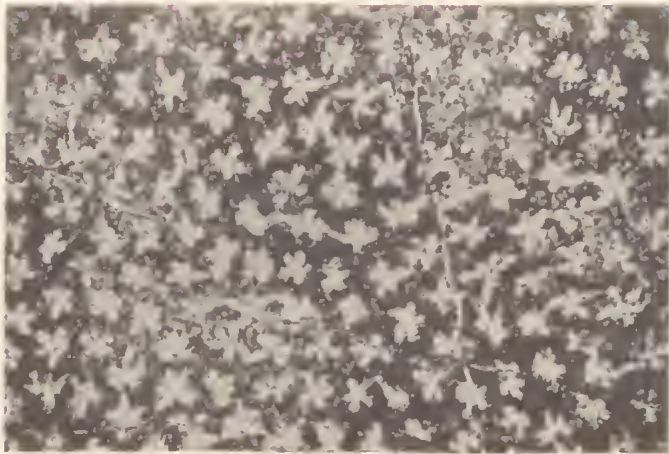
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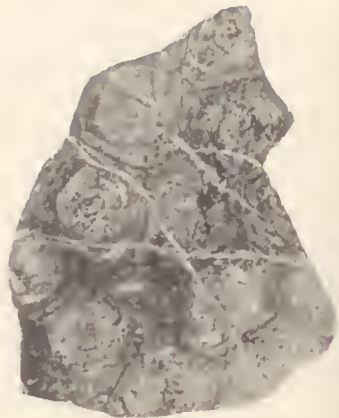
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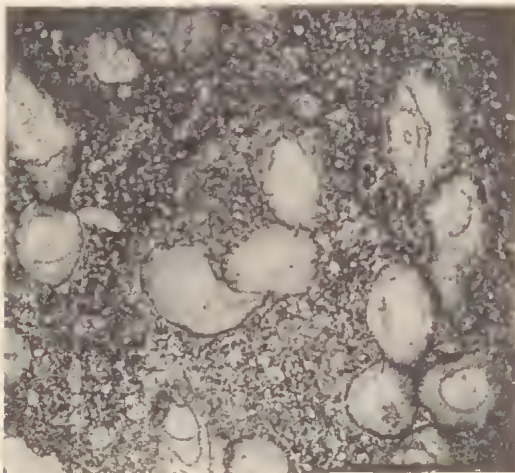
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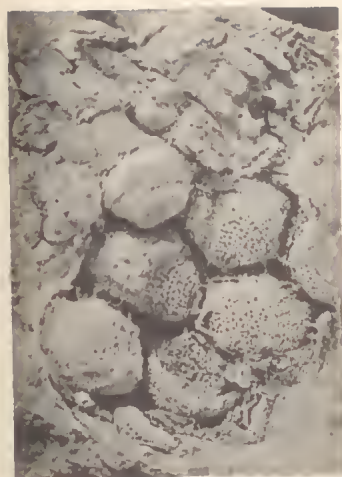
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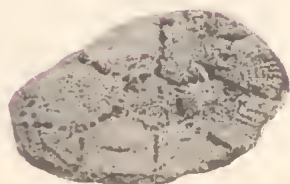
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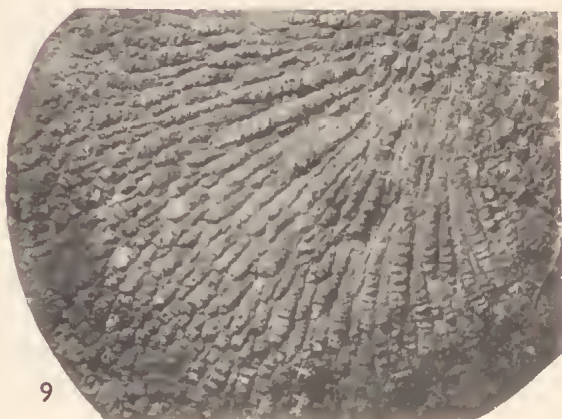
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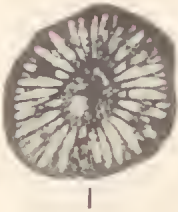
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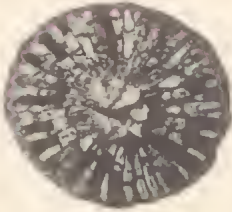
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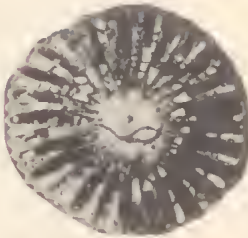
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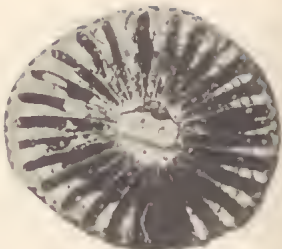
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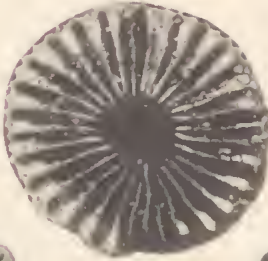
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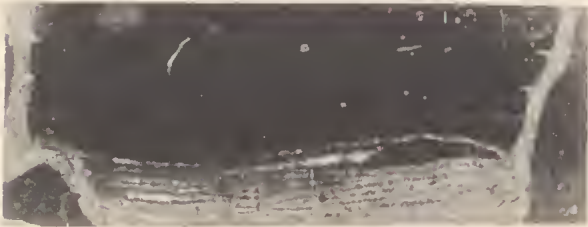
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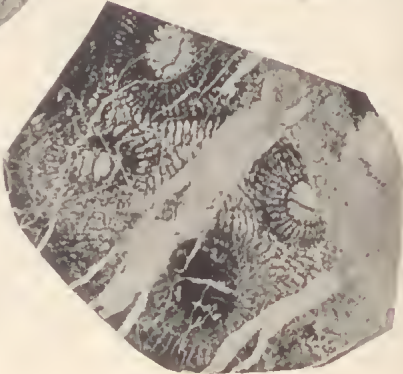
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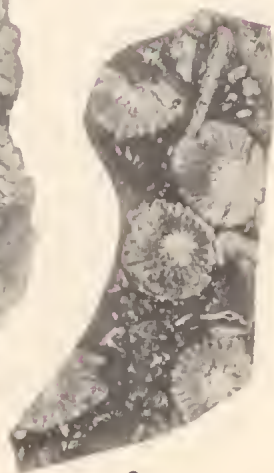
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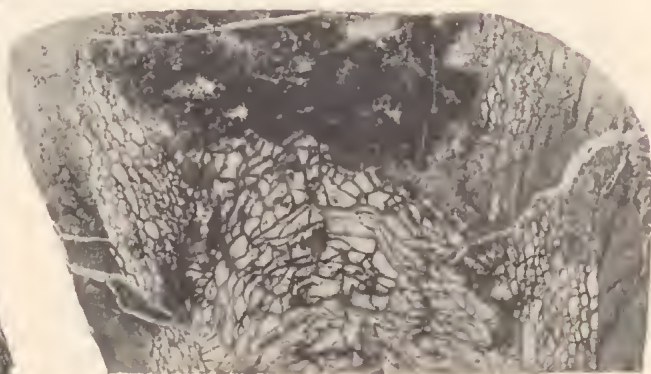
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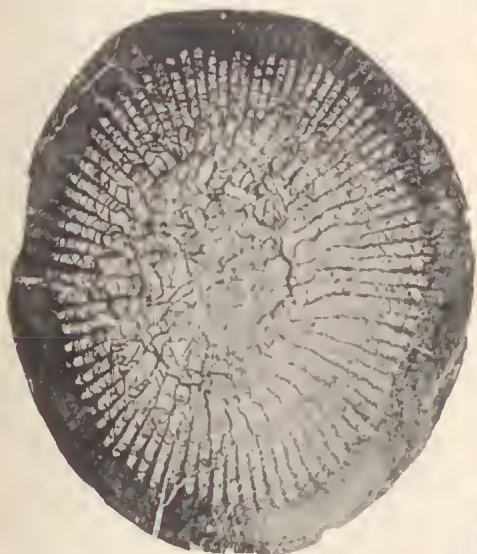
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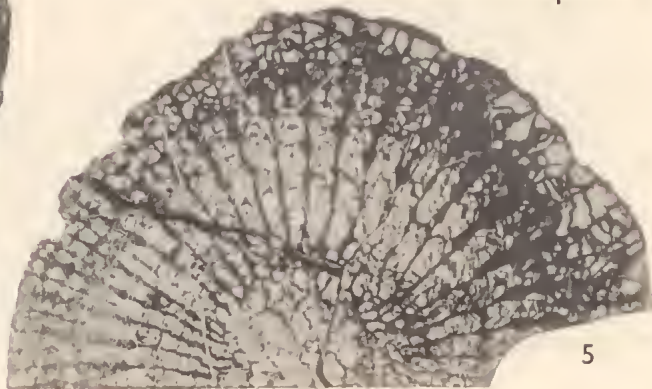
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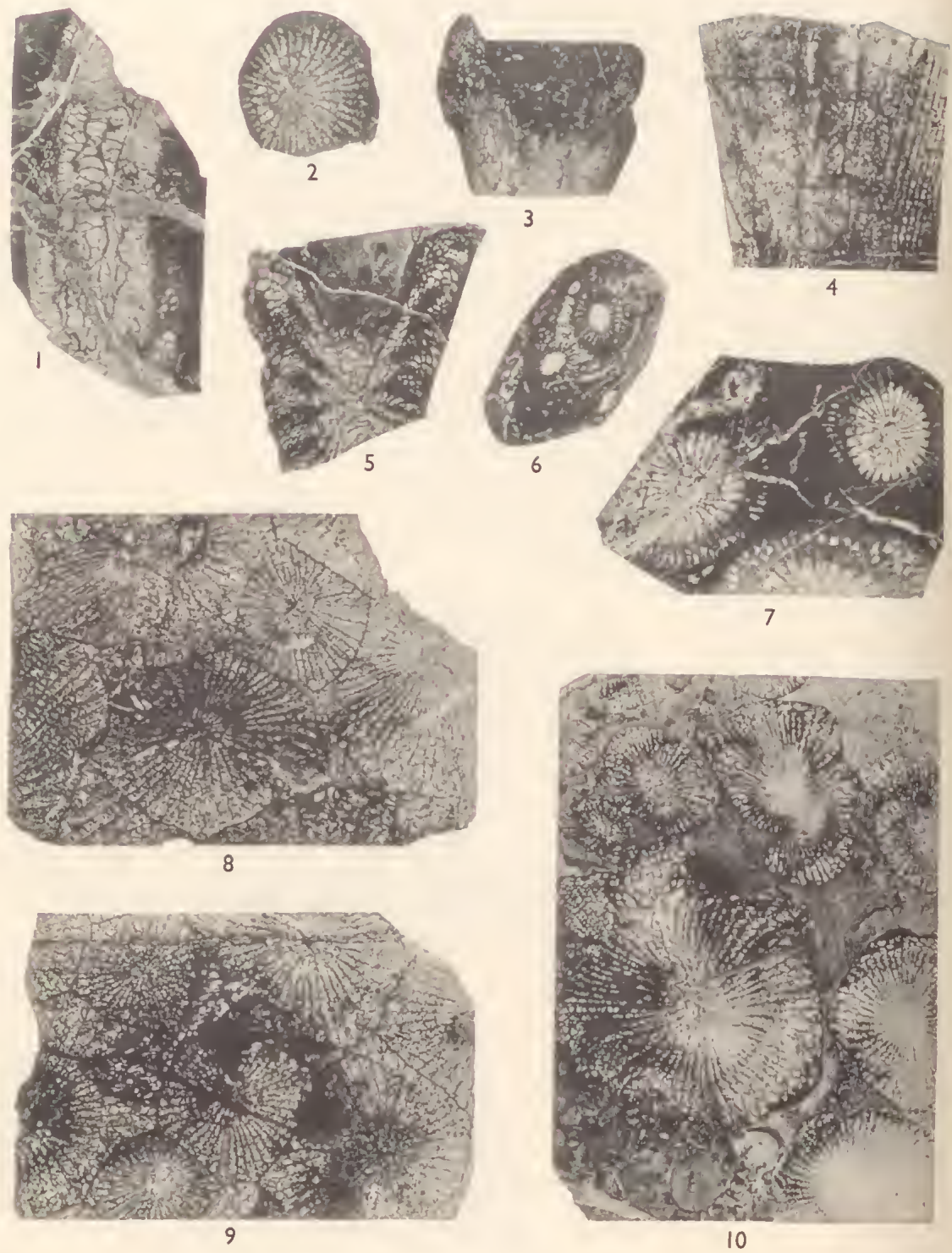
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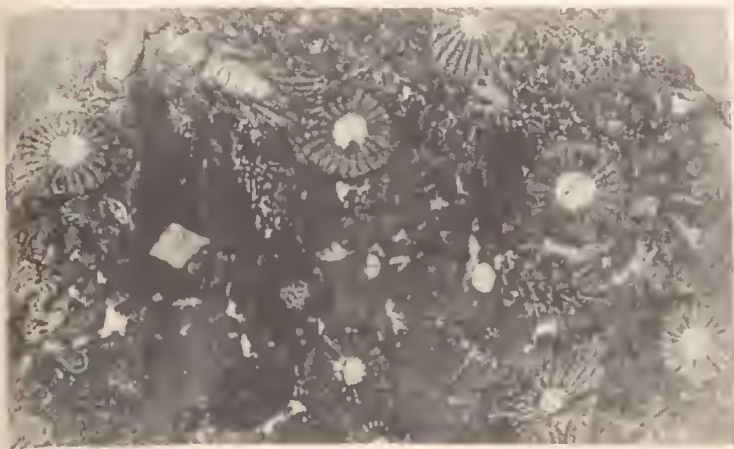


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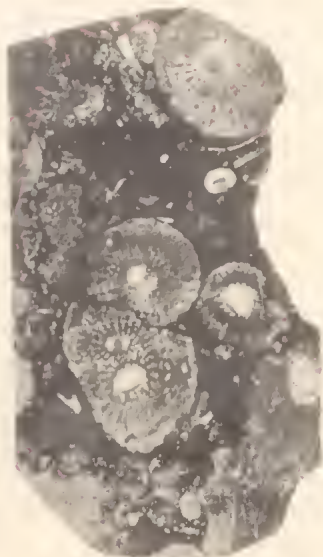


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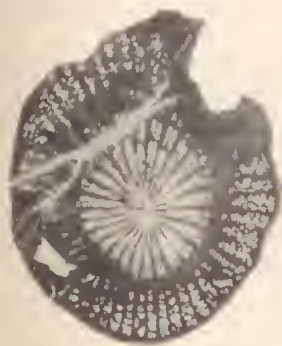




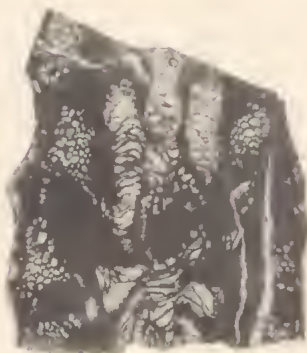
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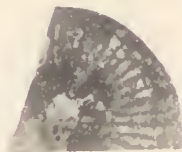
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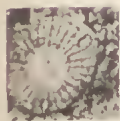
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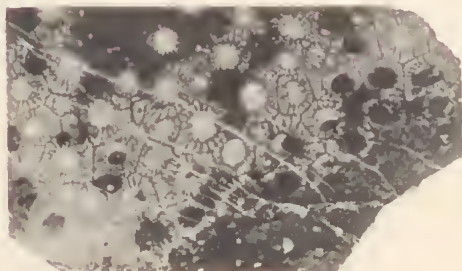
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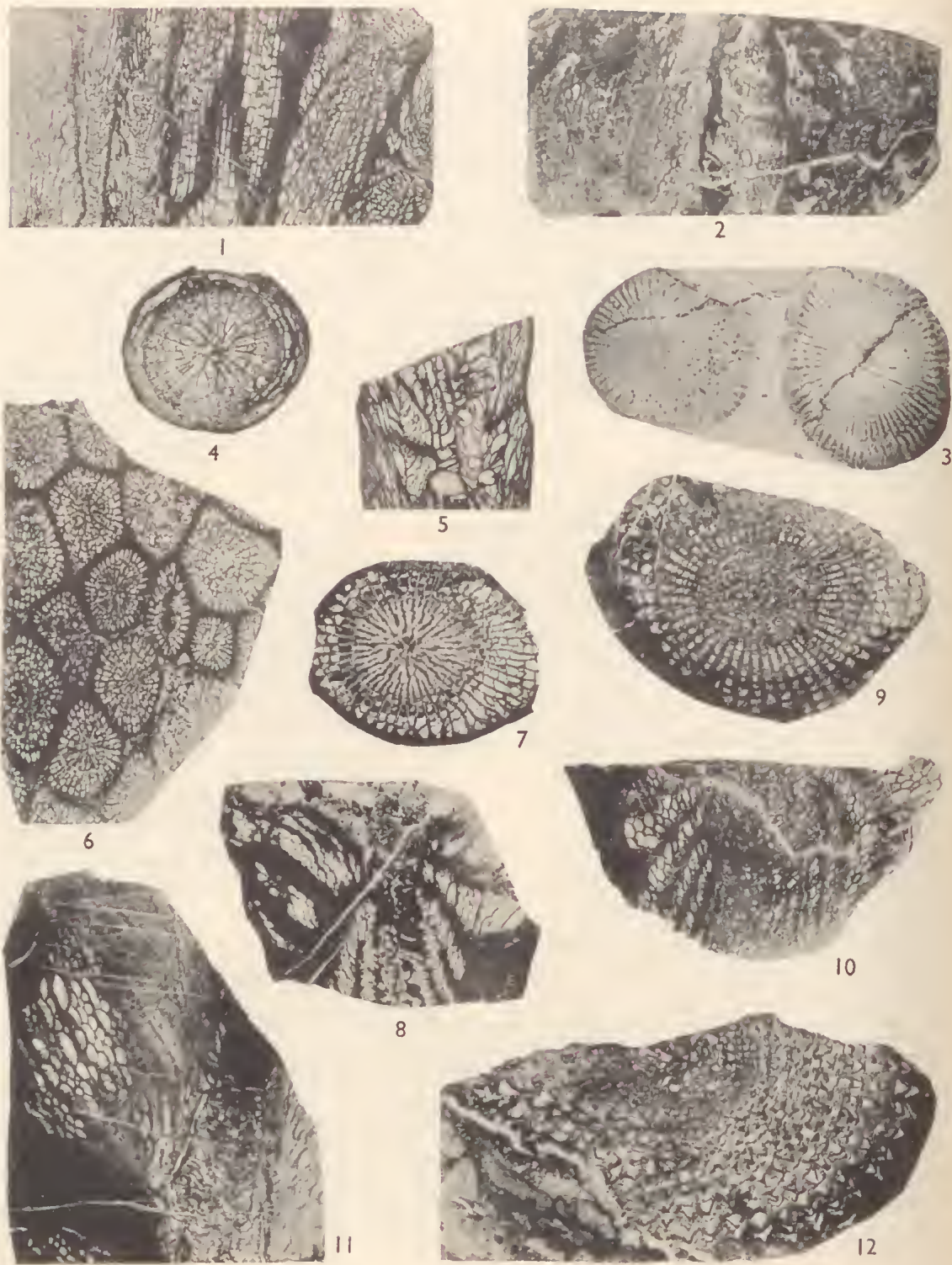
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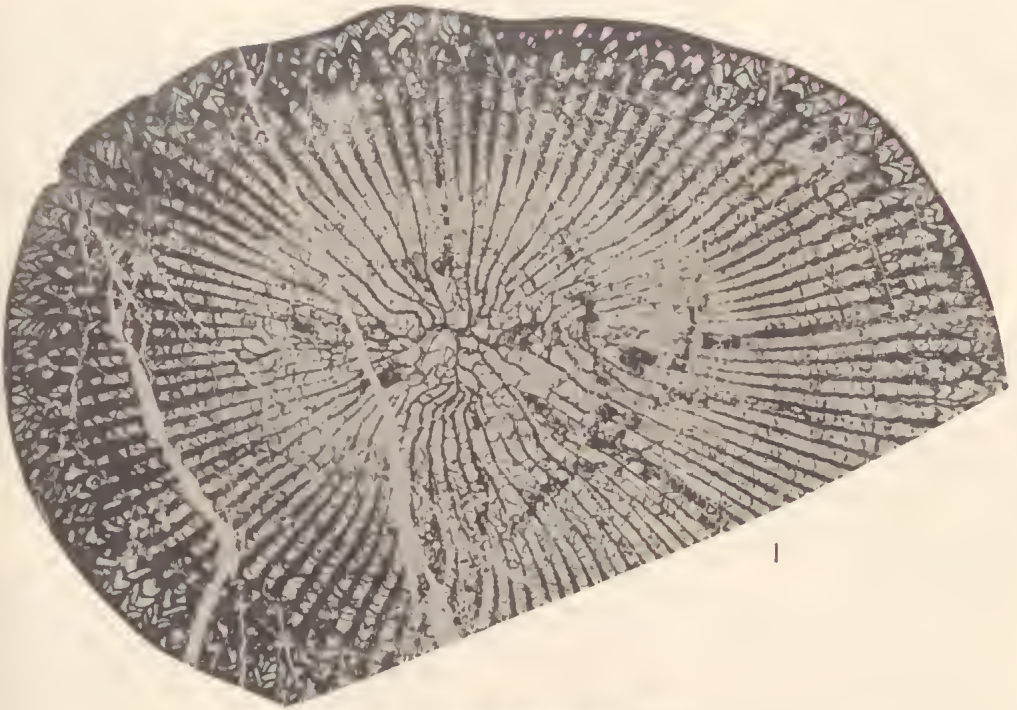


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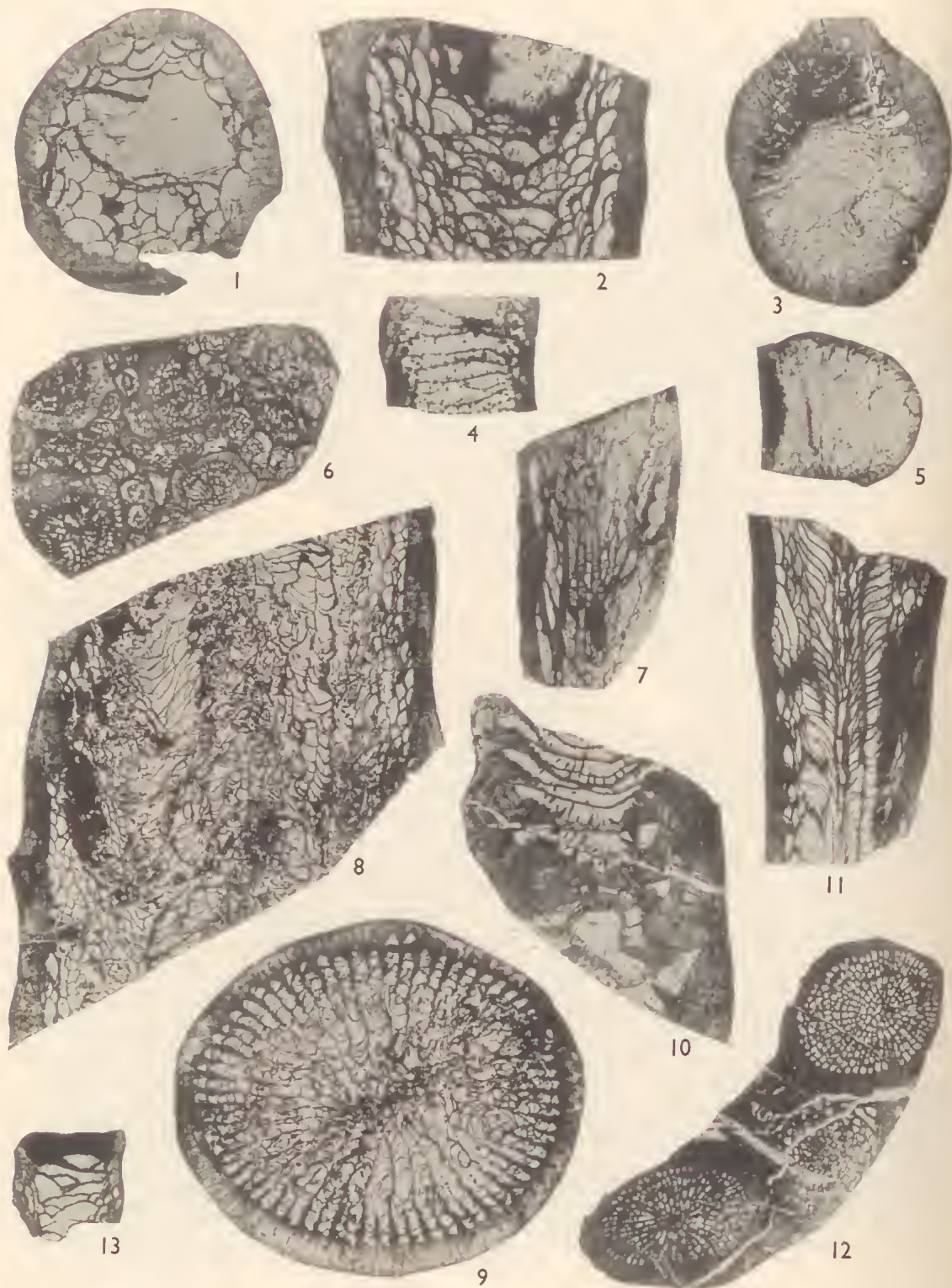


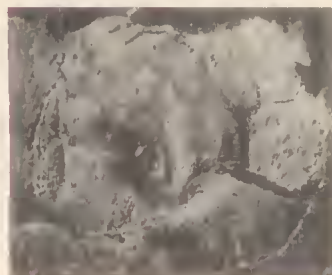
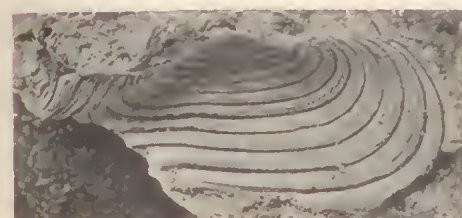
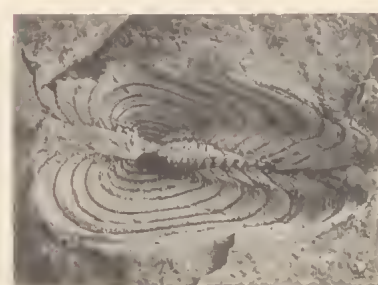
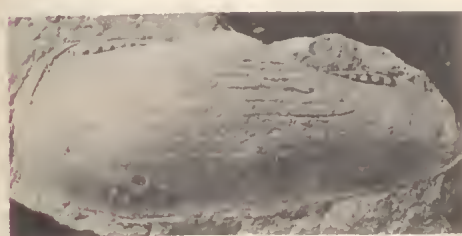
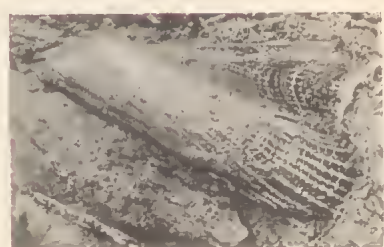
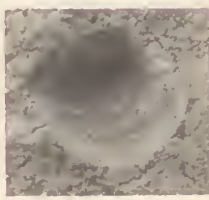
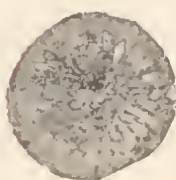
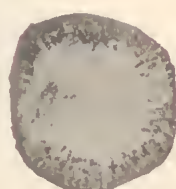
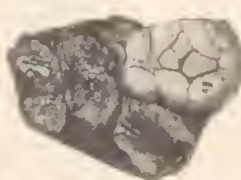
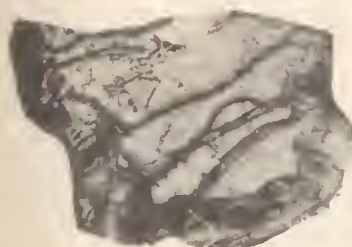


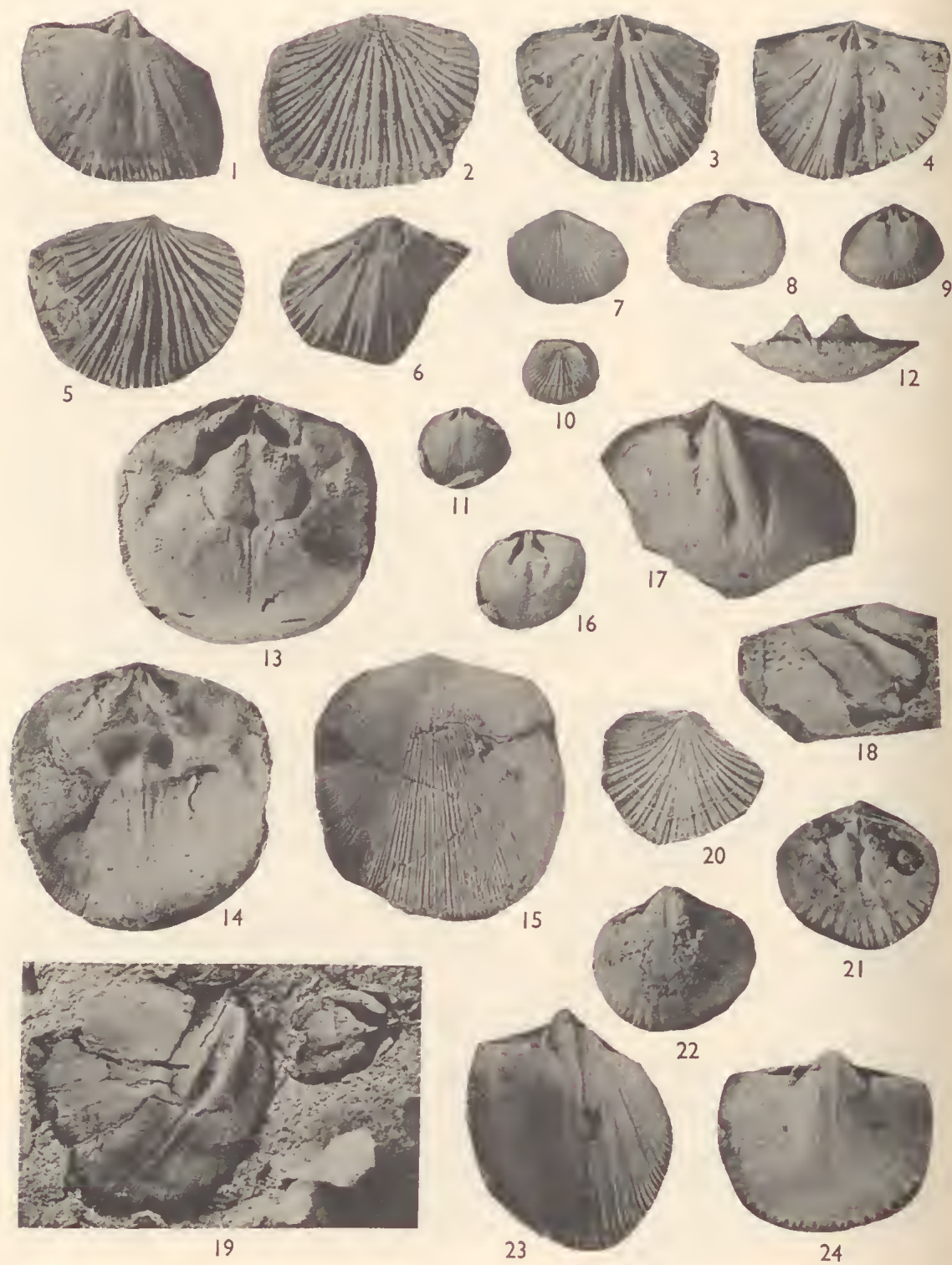
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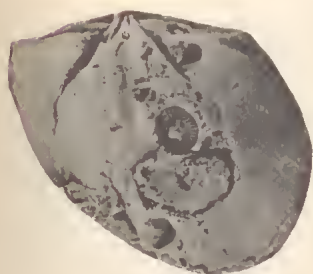


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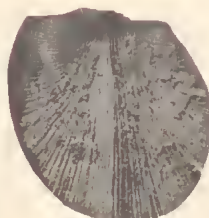
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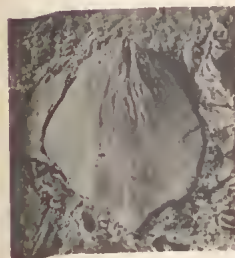
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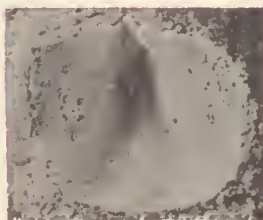
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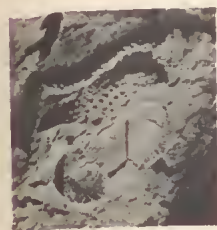
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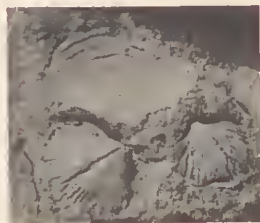
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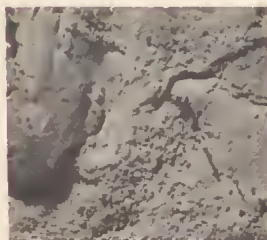
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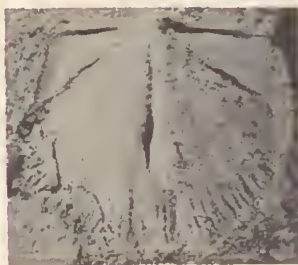
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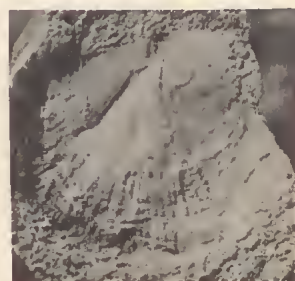
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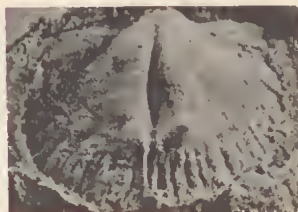
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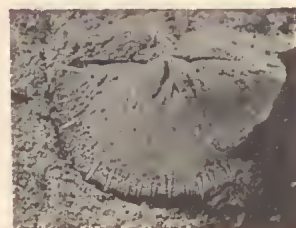
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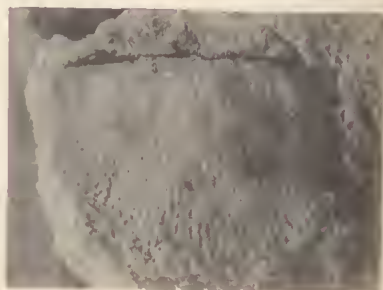
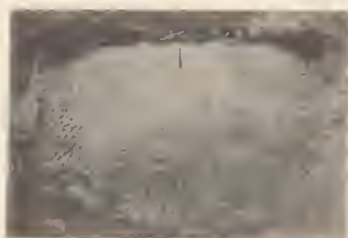
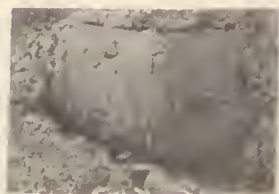
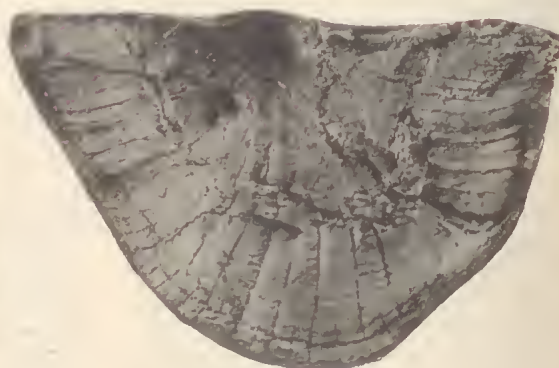
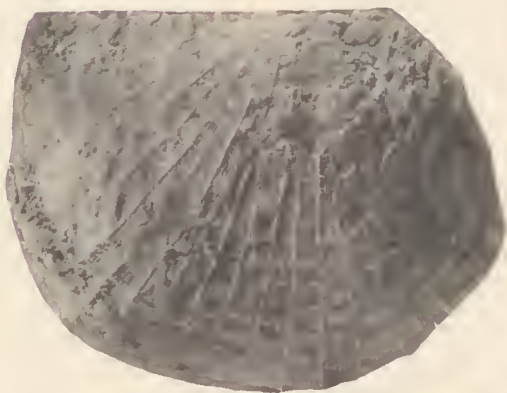
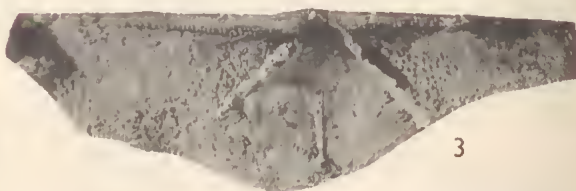
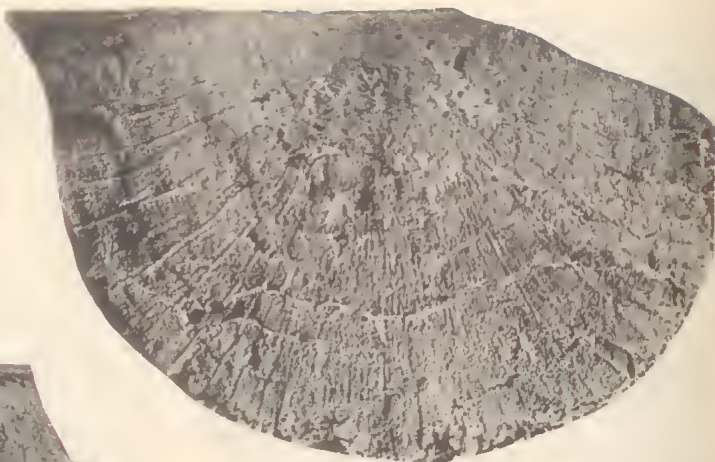
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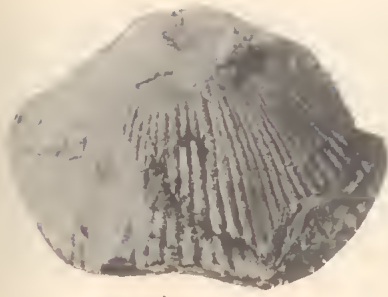
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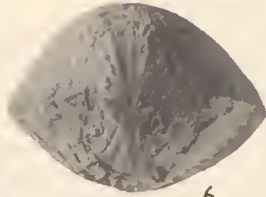
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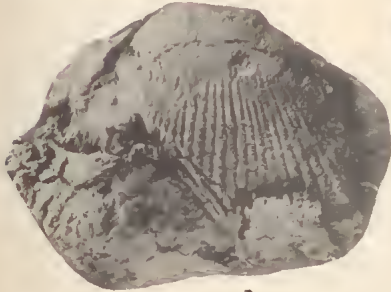
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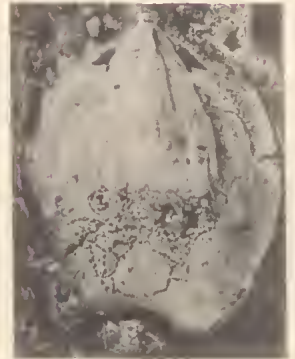
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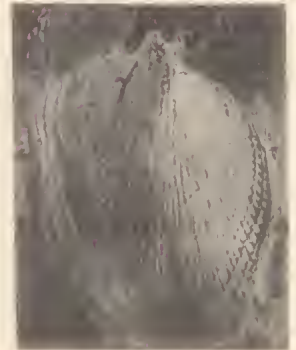
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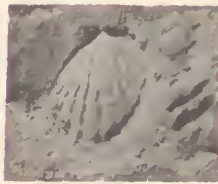
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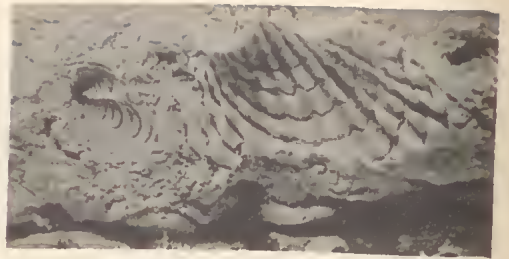
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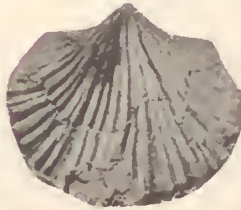
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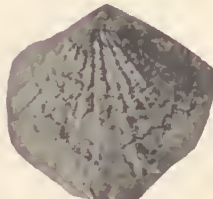
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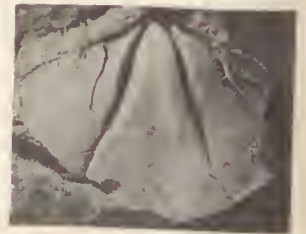
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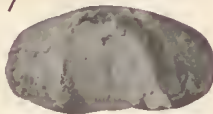
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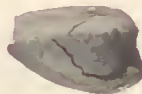
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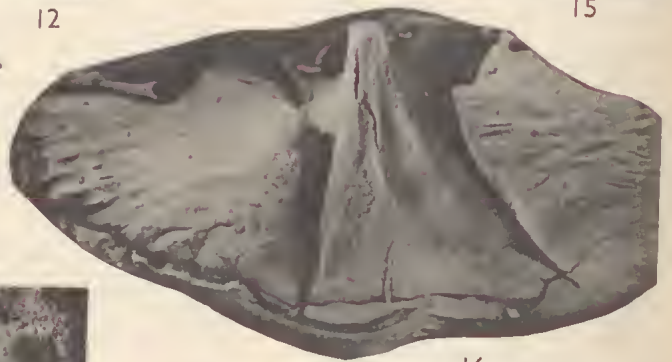
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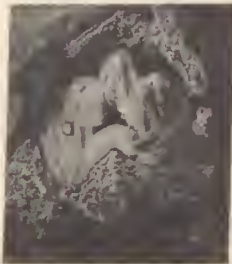
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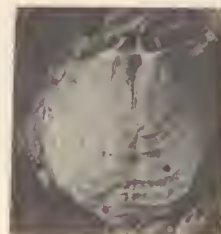
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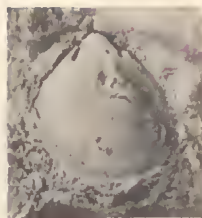
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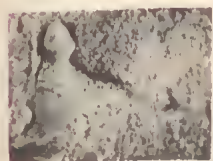
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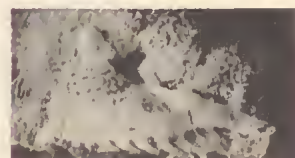
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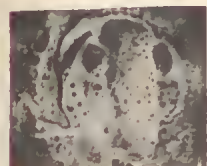
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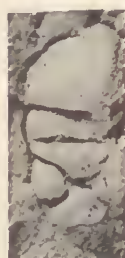
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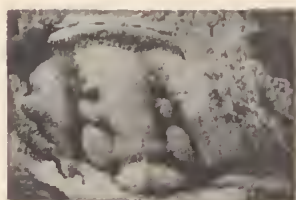
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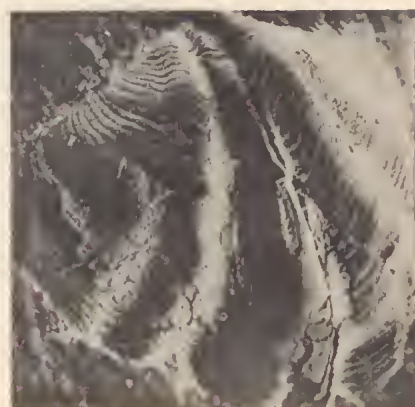
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9



16



18



15



17



Leptostrophia etc. affording not the slightest indication of Devonian age. The fauna thus contains many of the elements of the Ludlow (and even Wenlockian) faunas of Europe, Russia, and, to a lesser extent, North America.

I have previously (1960, p. 147-150) pointed to the difficulties which are encountered in endeavouring to arrive at a confident decision as to the age of the Tyers strata in reference to the European sections. First among these was listed the observation that hitherto no satisfactory correlation has been made of the European marine sequences which span the Siluro-Devonian boundary, particularly those of Bohemia and Podolia. In Bohemia the Koněprusy Limestone has varied from Gedinnian to Emsian in age with the several authorities. As these eastern European sequences are those with which, because of faunal similarity, the marine sequences of eastern Australia are to be correlated, a further uncertainty is introduced in any proposed correlation.

This difficulty is now for the major part resolved through the recent study of the lower Gedinnian brachiopod fauna of Belgium by Boucot (1960). Boucot's paper contains a brief account of the succession of Upper Silurian to Lower Devonian brachiopod faunas of Europe, and a convincingly documented scheme is proposed for the troublesome European marine sequences.

The correlations relevant here are first the equivalence of the Köbblinghäuser Schichten of Sauerland, the Calcaire de Liévin of Artois and the Étage de Skala of Podolia (a correlation suggested by Shirley 1938), which are all considered to be younger than Ludlovian, yet older than Gedinnian (thus, according to Boucot, there is a time gap in the existing marine stages). In Podolia the Gedinnian age of the Étage de Borszczów is established (cf. Philip 1960, p. 147), while in Bohemia, Boucot suggests that e-beta or e-gamma may be equivalent to the lower Gedinnian of Belgium.

Also of considerable importance here is the fact that Boucot recognizes for the first time among the lower Gedinnian brachiopods of Belgium the Silurian genus *Dolerorthis*. This, together with the fact that the Borszczów (with *Lissatrypa*, *Resserella* and *Plectodonta*) may now be regarded as Gedinnian in age, gives rise to a revision of the age of the fauna of the Boola Beds. Of the so-called Ludlow brachiopod genera listed above, which were considered as indicating a Silurian age for the Boola Beds, *Plectatrypa* alone remains. However this genus is abundantly represented in the so-called 'Marginalis' Beds of Asiatic Russia, which are best regarded as Gedinnian in age.

The brachiopod fauna of the upper part of the Boola Beds may then be considered as Ludlovian or lower Gedinnian in age.

Boucot (*op. cit.*) places considerable importance on the entry of terebratuloid brachiopods in the chronology of the Lower Devonian. The Gedinnian is characterized by the entry of such brachiopods together with *Proschizophoria* and *Cyrtina*.

Of critical importance, therefore, is the occurrence in the Boola Beds of a terebratuloid brachiopod. The few fragments collected were originally held over from the systematic part of this paper (with a number of other generically indeterminate fragments) until more material became available for study. At Dr Boucot's suggestion (and with the editor's kind permission) I have introduced photographs (Pl. XXXVI, fig. 1-2) of the most complete specimen to document this important occurrence.

The specimen (M.U.G.D. 3491) is the internal mould of the ventral valve of a form with well developed teeth, but lacking dental lamellae. The musculature is

obscure. No worthwhile comparison can be made with other terebratuloids. The affinities of the specimen are indicated by the traces of punctation which is typically terebratuloid. The specimen is from Loc. 43 in the Boola Beds, from whence come the other fragments in the collection.

Together with its associates, the occurrence of this form reasonably establishes a Lower Gedinnian age for the upper part of the Boola Beds.

Also relevant to the age of the Boola Beds is the work of Jaeger (1959). Jaeger has suggested that the form hitherto identified as *Monograptus uncinatus*, occurring with the vascular land plant *Baragwanathia* at the base of the Tanjil Beds, is rather *M. hercynicus*. Dr Jaeger (*in litt.* 7 January 1961) has now had opportunity to examine specimens of this form and rather compares it with his *M. praehercynicus* which in Thüringia occurs in reputed equivalents of e-gamma of the Bohemian sequence. Dr Jaeger has in preparation a note on the identity of this graptolite. This means that the *Baragwanathia* horizon, although probably not Devonian in age (i.e. as young as the Gedinnian), is very high in the Silurian (perhaps even post-Ludlow), which removes half of the time discrepancy which has been seen in the occurrence of this, the first vascular land plant.

Mention may be also made of a recent paper containing descriptions of a Gedinnian coral fauna from Maine, U.S.A. (Oliver 1960). The corals of the Coopers Creek Formation, in comparison with those of Europe, give an upper Lower Devonian age for the formation. This has led me to suggest a certain homotaxy exists in these faunas. Of interest, then, is the resemblance of the Maine fauna with that described in this paper. This would seem to support my previous contention (1960, p. 149) that the apparent homotaxy is an artefact of incomplete knowledge of (or, in Australia, the lack of recognition of) Lower Devonian coral faunas.

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Explanation of additional plate

PLATE XXXVI

Internal mould of the ventral valve of a generically indeterminate terebratuloid brachiopod from Loc. 43, Boola Beds. M.U.G.D. 3491. (1) x 15. (2) Enlargement of punctae. x 25.

THE BOTANY OF THE VICTORIA EXPLORING EXPEDITION
(SEPTEMBER 1860—JUNE 1861)
AND OF RELIEF CONTINGENTS FROM VICTORIA
(JULY 1861—NOVEMBER 1862)

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[Read 10 November 1960]

Introduction

The Victoria Exploring Expedition was by no means the first to make botanical observations and collections in the far W. of New South Wales or the border regions of South Australia and Queensland. Earlier investigators in these tracts were:

1. MAJOR T. L. MITCHELL who, in July 1835, came down the Darling from present Wilcannia to near Menindee. His official botanist, Richard Cunningham, had perished near Dandaloo on the Bogan R. during May, but Mitchell collected a few plants along the Darling, including the original specimens of Sweet Fenugreek or 'Menindee Clover' (*Trigonella suavisissima*) which he described as 'certainly the most interesting plant hitherto found by us'—he was impressed by its powerful sweet aroma and value as a delicious substitute for spinach.

Again, during May and June 1836, Mitchell was in the Murray Valley between Wentworth and Swan Hill, from which area he collected the type material of at least 8 plants. All his botanical gatherings were studied in England by Lindley who published any novelties as footnotes to Mitchell's narrative *Three Expeditions into the Interior of Eastern Australia* (1838).

2. CAPTAIN CHARLES STURT who, from Sept.—Oct. 1844, journeyed 100 m. from Wentworth to Menindee along the Darling valley, turning then NW. into the Barrier Ra. Between August and November 1845 Sturt covered a large part of the NE. corner of South Australia (including Cooper Cr.), also Stokes Ra. in Queensland and beyond Birdsville to a point on the Queensland-Northern Territory border between the Hay and Field R. courses. From this exploit Robert Brown in England received approximately 100 plant species, describing the new ones as an appendix to Sturt's *Narrative of an Expedition into Central Australia* (1849).

3. AUGUSTUS GREGORY who, in May—June 1858, travelled down the Cooper and Strzelecki Cr. from SW. Queensland to search for traces of Dr Leichhardt. F. Mueller contributed a paper 'Enumeration of plants collected by A. C. Gregory, Esq., along and near Cooper's River and its tributaries in Subcentral Australia' which was published as part of the *Votes and Proceedings of the Legislative Assembly of New South Wales* for the Session of 1858-59, 2: 4-10 (1859). 70 species were listed, 5 being described by Mueller as new to science.

4. JOHN DALLACHY and the REV. T. H. GOODWIN, who also followed the Darling from Wentworth as far as Wilcannia, collecting many plants for Mueller in Nov. 1858.

Although a century has now passed since Robert O'Hara Burke and William J. Wills began their ill-fated journey across Australia, and although the Victorian Government's expenditure on this undertaking was far more lavish than for any other exploratory venture, no comprehensive account of the botanical results has ever been published. Indeed, the only printed references available are F. Mueller's descriptions in Latin of sundry new species in Vol. 3 of his *Fragmenta Phytographiae Australiae* (1863), the citations (often erroneous) of collections scattered through the 7 volumes of G. Bentham's *Flora Australiensis* (1863-78) which embrace 324 species (16 of which are not now represented in Melbourne Herbarium by any specimens from the Expedition), and a few letters from various members of the expedition published in the Melbourne *Argus* between Nov. 1860 and Aug. 1861. To these sources may be added the list of 114 species collected on Howitt's subsidiary expedition to far NE. South Australia in 1862, which was published by Mueller in his *Annual Report* to Parliament, 15 Apr. 1863. All botanical material came to Mueller who, as early as 27 May 1861, exhibited at the Royal Society of Victoria 'some plants collected by Dr Beckler'. These and subsequent gatherings are now housed in the National Herbarium, Melbourne, where there is evidence that, during the main expedition and two relief parties under Howitt's leadership, some 708 separate collections of vascular plants were made. At least 393 species are involved in this total, including type specimens of 37 new species and 3 varieties. Apparently no bryophytes, lichens or fungi were collected.

A concise review of who were the botanical collectors, where they went at various times, and what they found, is a desideratum that the following pages endeavour to meet. As a background to any such account, it would be advantageous to give a brief chronological résumé of the principal movements in the main expedition and various relief parties, thus:

1860

- 20 Aug.—Expedition leaves Melbourne, taking 13 days to make Swan Hill. Dr Herman Beckler is the medical officer and botanist; Dr Ludwig Becker the artist, naturalist and geologist.
- 12 Sept.—Crossing of the Murray into New South Wales.
- 15 Sept.—Arrival at Balranald, proceeding then to L. Paika, Tjerrikenkom, Bokoo, Prungle and Arumpo homesteads, Garnpang water-hole, and the banks of the Darling at Pooncarie by 25 Sept. The leaders, with Professor George Neumayer, had gone ahead of the main party which did not reach the Darling until 4 Oct. Neumayer returned to Melbourne, after having helped to organize observations in physical science and astronomy. The expedition then moved up the E. bank of the Darling, past Bilbarka and Tolarno to Kinchega where it crossed to Mr W. Wright's station on the W. side.
- 16 Oct.—Arrival at Menindee, 2 months after leaving Melbourne, and establishment of the base camp a few miles upstream at L. Pamamaroo. George J. Landells, second-in-command, resigns after repeated quarrels with Burke and goes back to Melbourne; Wills, the young surveyor, is appointed to take his place.
- 19 Oct.—Burke and Wills, Brahe, Wright (who was persuaded to join the party as local guide) and 6 others push on ahead toward Cooper Cr., while scientists Beckler and Becker stay with the remaining men and supply of stores on the Darling.
- ±30 Oct.—From Torowoto Swamp (about 44 m. ESE. of Milparinka and 70 m. S. of the Queensland border) Wright is sent back to Menindee with instructions

to bring up the remainder of the party and supplies without undue delay—he actually delayed 3 months, spelling disaster for the whole expedition.

- 11 Nov.—Burke, Wills, Brahe and the 6 men with them reach Cooper Cr. and form another base depot, where they await Wright's appearance with the stores.

- 16 Dec.—After waiting 5 weeks, and impatient at Wright's dilatory behaviour, Burke strikes out for the Gulf of Carpentaria in company with Wills, King and Gray, leaving Brahe in charge of 4 men at Cooper Cr. with instructions to remain there 3 months until his anticipated return within that period.

The expedition was thus split into three distinct, isolated parties, with virtually no means of intercommunication. Ernest Favenc, in his *History of Australian Exploration from 1788-1888*, p. 211 (1888), makes a trenchant criticism of this situation in the following terms:

Burke, during the most important part of his journey, left behind him his botanist, naturalist and geologist, and started without even the means at his disposal of following up any discoveries he might make. His sole thought evidently was to cross to Carpentaria and back, and be able to say that he had done so—a most unworthy ambition . . . this tramp, for perverse absurdity, stands unequalled. . . . After all the pains and costs expended in the organization of this expedition, we have now the spectacle of the main body, including two of the scientific members, loitering on the outskirts of the settled districts.

1861

- 11 Feb.—Burke, Wills and company reach the Gulf country (near the mouth of Norman R.), but cannot get any glimpse of the sea because of a wide impassable belt of mangroves around that flat muddy coast. Much weakened, they commence the tedious journey back on 21 Feb., apparently without collecting a single natural history specimen.

Attention may here be diverted to the main base camp on the Darling, 1030 m. S.

- 26 Jan.—Wright, Beckler, Becker and others set out at last from L. Pamamaroo near Menindee and head N. through Scrope Ra., Mootwingee, the Noon-thorangee, Teltawongee and Wonominta Cr., past Mt Koonenberry and Pal-drumata to Torowoto Swamp by 12 Feb. Soon after attaining this point (70 m. short of the Queensland border) Wright records that the advance of summer drought and the ravages of scurvy 'reduced the effective strength of my party to an alarming extent'. For two more months he struggles on, with gradually exhausted men.

- 6 Apr.—Wright makes camp on the Bulloo R., ahead of Beckler who was attending to two very sick men at Kooliatoo Cr., and builds a stockade there. He is attacked by hostile aborigines.

- 22 Apr.—Wright's Bulloo stockade is attacked again, within 24 hours after the arrival of Beckler, Becker and Purcell. Stone dies this day, Purcell succumbs the day following and Becker on the evening of 29 Apr.

By the 27 Apr. Wright had decided on an immediate retreat to Torowoto 'to recruit the sick and obtain fresh stores from the Darling'.

- 21 Apr.—Brahe, having waited more than the requested 3 months for Burke's return and having failed to be re-provisioned from the Darling, abandons the depot on Cooper Cr. A week later (on the evening of 28 Apr.) he finds Wright immobile with sick and worn-out men at the Bulloo R. camp.

- 3 May—Brahe and Wright set out together for Cooper Cr. again, arriving on 9 May, in a last attempt to ascertain whether Burke had come back from the Gulf. They fail to note any evidence that Burke, Wills and Gray had actually reached the depot on 21 Apr.—only 7 hours after Brahe's departure! From the

Bulloo stockade Brahe, Wright and their united parties make all possible speed back to Menindee (reached on 18 June) whence Brahe comes on alone to Melbourne with dispatches. A fourth man (Patton) died on 30 May.

- 29 June—Wills dies on Cooper Cr., and 2 days later Burke succumbs about 15 m. upstream, after their futile attempt to reach Adelaide via Mt Hopeless station. King is cared for by aborigines, but Gray had perished just before the fateful return to Cooper Cr. on 21 Apr.

Now follow the activities of the 5 relief parties, of which A. W. Howitt's 2 contingents were the most productive:

- 5 July—Howitt leaves Melbourne with party of 12 (including Brahe) to search for Burke and Wills. He stays 5 days in Swan Hill and reaches Menindee sometime before 3 Aug. when he communicates with Melbourne.
- 13 Sept.—Howitt reaches Cooper Cr. depot, via Stokes Ra., and 2 days later King is discovered still alive, although 'wasted to a shadow'. By 21 Sept. the bodies of Wills and Burke are found and buried. Howitt and party then hasten S. again, Brahe racing ahead and reaching Bendigo with the tragic news on 2 Nov.
- 9 Dec.—Howitt sets out on a second journey to Cooper Cr., primarily to bring back the remains of Burke and Wills for burial in Melbourne; he arrives at the depot on 2 Mar.

On this expedition, of 10 men, there was no need for haste, and Howitt was away for just a year. Between Mar. and Sept. 1862 he made 5 separate sorties from Cooper Cr.—S. along Strzelecki Cr. to L. Blanche and the N. parts of Flinders Ra., NW. across the Diamantina R. to beyond Birdsville. He gained the confidence of the Dieri aboriginal tribe and accumulated much valuable information.

1862

- 22 Oct.—Howitt arrives at Blanchewater station for the fourth time (from Cooper Cr. depot), now bearing the remains of Burke and Wills. He is at Angipena station on 21 Nov. and Adelaide on 8 Dec.
- 27 Dec.—Howitt reaches Melbourne by ship from Adelaide, and the public interment of Burke and Wills's remains takes place on 21 Jan. 1863.

Meanwhile, during the latter part of 1861 and early in 1862, 3 other search parties had been operating simultaneously:

1. JOHN MCKINLAY (16 Aug. 1861—June 1862) had gone from Adelaide N. to Cooper Cr. depot and across Queensland to the Gulf (as near to Burke and Wills's route as possible), then SE. through North Queensland to the coast at Port Denison.

2. WILLIAM LANDSBOROUGH (14 Aug. 1861—21 May 1862) proceeded from Brisbane by ship to the Gulf of Carpentaria near the mouth of Albert R., then overland to the Warrego R. settlements.

3. FREDERICK WALKER (7 Sept. 1861—early Apr. 1862) went from Rockhampton NW. to the Gulf.

Into this rather complex framework of events fit the several botanical collectors associated with the Victoria Exploring Expedition, and not one of them was a trained botanist. No plant specimens would seem to have been gathered during Walker's journey. McKinlay's search party from Adelaide and Landsborough's from the mouth of Albert R. (on the Gulf) were each responsible for several plant

recordings. Diedrich Henne was botanical collector during Landsborough's voyage N.; he gathered specimens on Whitsunday, Gloucester and Cairncross I. in Torres Str., Curtis, Palm and Sweers I. (at the S. extremity of the Gulf), but did not accompany Landsborough overland through N. Queensland. These few botanical collections, representing chiefly tropical species, have little bearing on the achievements of the Victoria Expedition itself and they have not been taken into consideration in the present paper; suffice it to say that McKinlay brought back excellent material of the nardoo plant (*Marsilea drummondii*) which had helped to keep King alive after the deaths of Burke and Wills.

Botanical Collectors

DR HERMAN BECKLER, MD

Pre-eminent among the contributors of plant specimens was the medical officer and botanist to the original expedition. His 475 collections, embracing slightly more than 300 species, were made between the Murray R. at Swan Hill (12/9/1860) and just beyond the Queensland border (31/3/1861, at Kooliatoo Cr. toward Bulloo L.); Beckler then returned to the Darling at Menindee, and apparently made his last collection on 29 June 1861. He was a careful, painstaking collector who had already achieved distinction in SE. Queensland (Moreton Bay, Mt Mitchell and Warwick districts) as well as in the Clarence and Hastings R. regions of New South Wales. His field labels in Melbourne Herbarium indicate that Beckler obtained specimens from at least 26 collecting sites, while with the Victoria Exploring Expedition; the 12 between Swan Hill and Menindee cover one month's work (14 Sept.—14 Oct. 1860) during the Expedition's early phase—viz. Wakool R., L. Yanga, Balranald, L. Paika, Tjerrikenkoim, Prungle and Arumpo station homesteads, Coles Waterhole, Garnpang, Bilbarka on the Darling and Mr Cloud's station near Tolarno.

That Beckler was also no mean artist is apparent from several sketches bearing the initials 'H.B.' and now accompanying those of Ludwig Becker, the official naturalist, in the archives of Melbourne Public Library. Much of his botanical material came from around L. Pamamaroo on the Darling, where he was 'bogged down' during W. Wright's long period of inactivity. One pleasant and fruitful diversion at this time was an excursion to Scrope Ra., about 43 m. E. of Broken Hill, from 5-7 November; he was accompanied by Mr Hodgkinson and an aborigine, and they camped at Kokriega Well (Burke's Camp No. 36, now called 'Burke's Cave'). Of these wild, rocky conglomerate hills (6-7 m. across and estimated as up to 500 ft high) Beckler wrote on 13 November 1860 (Letter to Dr John Macadam, published in the Melbourne *Argus* of 4 Dec. 1860. Two other 'Notes on Plants' were received by the Exploration Committee on 5 Feb. 1861, but cannot now be traced.):

After having found some plants, new to me, on the rocky parts near the gully, I hoped to find a greater variety still between the hills. In this I was mistaken, the vegetation of the central parts being much poorer than the rocks and the gullies on the circumference of the mountains. . . . Groups of a small kind of *Casuarina* cover parts of the hills, the ground being covered with different salsolaceous plants which prevail all over the hills. I found a good few different herbs of the *Malvaceae*, a few grasses, two or three species or varieties of a genus of the (?) *Saxifragaceae* ["*Saxindarias*" in newspaper report], a shrub with a beautiful blossom like a *Styphelia*, and some composite plants—one of which, growing on rocks and in crevices, exhaled such a disagreeable odour that I could not stand near it for many minutes without feeling my head ache. . . . Most of the shrubs growing in the hills are just now in blossom. I collected as many specimens as I could.

At least 50 species were represented among the plants collected on Scrope Ra. which, on Beckler's field labels, is rendered as 'Goginga Mountains'—probably his

attempt to spell the aboriginal sound otherwise interpreted as 'Kokriega'. From a high eminence on Scrope Ra., Beckler saw a 'long, considerable range of mountains' bordering the W. horizon and seeming to be from 35 to 70 m. distant. This, undoubtedly, would be the Barrier Ra. which he never reached; but in *Flora Australiensis* (1863-78) Mueller and Bentham incorrectly assign many Scrope collections to the former locality, even stretching the limits of the 'Barrier Range' to include remote Mt Koonenberry (in the Coturaundee Ra., some 110 m. NE. from Broken Hill).

Between 19 Dec. 1860 and about 10 Jan. 1861 Beckler journeyed from Menindee N. to Torowoto Swamp (44 m. ESE. of Milparinka), and secured samples of at least 60 plant species during the round trip of some 330 m. His four principal collecting places were Noonthorangee Cr. (24 Dec.), Torowoto Swamp (27-28 Dec.), Mt Koonenberry (31 Dec.) and Mootwingee (3 Jan.)—rendered on his field labels as 'Nandurungee', 'Duroadoo', 'Goningberi' and 'Mutwanji' respectively. Wright had sent him to the relief of Macpherson and Police-trooper Lyons, of whom nothing had been heard since they set out to overtake Burke and party with dispatches from the Exploration Committee in Melbourne. Beckler found the two men, subsisting on 1 pint of nardoo per day in the vicinity of Torowoto; having lost their horses, they were destitute and faced with starvation in the heat of an inland summer. About this time, a consignment of plant specimens from Menindee reached Melbourne, for in Feb. 1861 Mueller described in his *Fragmenta Phytographiae Australiae* (2: 140) the saltbush *Kentropsis* [= *Bassia*] *eriacantha*—the Expedition's first botanical novelty to appear in print.

Only a fortnight after bringing Macpherson and Lyons back to the Darling camp, Beckler moved N. again over the same ground with Wright's whole party. Limited collections were made at Nootumbulla Cr. and nearby Bengoro Ra. (4-6 Feb.), Torowoto Swamp (13 Feb.—3 Mar.), Caryapundy Swamp (19 Mar.) and Kooliatoo Cr. (31 Mar.); the last locality, just beyond the Queensland border toward Bulloo L., apparently marked Beckler's most northerly collecting point. Thereafter he was fully preoccupied in caring for sick and exhausted men: four died during the drought-stricken, tragic months of April and May 1861, including the Expedition's artist-naturalist Dr Becker (on 29 April). In the final week of Wright and Brahe's combined retreat to the Darling, Beckler again collected some specimens at Wonominta Cr. (12 June), Mootwingee (13 June), 'Bodurga to Pilpa' (15 June) and 'Goginga Glen' (17 June). His last collecting days would seem to have been 28 and 29 June when a few plants were taken from 'sandhills near the Darling'—presumably at L. Pamamaroo.

It is regrettable that Herman Beckler was denied the opportunity to collect beyond the borders of New South Wales. He remained at Camp 1 on the Darling until after the arrival of A. W. Howitt's relief party from Melbourne at the beginning of August. Letters from Howitt (3 Aug.) and Beckler (6 Aug.) at Menindee reached the Exploration Committee on 22 Aug. 1861, the doctor remarking:

The collection of plants and a small case, filled with different objects of natural history by the late Dr Becker, will be taken down by the steamer which is now on her way to this place.

Beckler must have left for Melbourne about the end of that month, because he was available to accompany Professor G. B. Neumayer to the Mallee on 28 Sept. They went north-westerly through Bendigo, Charlton, Brim, L. Corong, Pine Plains, Kulkynne, Wentworth, Renmark and Blanchetown, reaching Wellington at the mouth of the Murray on 14 Dec. On 30 Dec. Beckler was back in Melbourne, under-

going interrogation at the final meeting of the Royal Commission of Inquiry into the conduct of the Burke and Wills Expedition; his recent plant collectings from W. Victoria and the Murray Mallee were handed over to F. Mueller. Thereafter, he fades completely from the botanical scene, and nothing is known concerning where and when he died.

A difficulty has been to identify and fix some of the localities mentioned on Beckler's field labels. His pencilled handwriting is often poor and indistinct, so that Mueller's label-writers misconstrued many spellings which were further corrupted in the pages of Bentham's *Flora Australiensis*. For instance, 'Goginya', 'Goyinga', 'Guginga', 'Gozinga', 'Yayinga', 'Yayinya', 'Yuyinya', 'Yuyingee' and even 'Toguya', are all obvious variants of the 'Goginga' used by Beckler; in fact, they refer to Scrope Ra. in the vicinity of Kokriega Well (now Burke's Cave). The only place names that have not been identified are 'Nangarna' (or 'Nangawera') and 'Yellow-inchi', both between Mt Koonenberry and Torowoto Swamp; the former may possibly be equivalent to Narnumpy. [See p. 255 for a Chronological Arrangement of Dr. H. Beckler's Collecting Places, with his spellings and sundry variations by Mueller and Bentham in parenthesis.]

WILLIAM WRIGHT

The leader of the unfortunate supply party from Menindee collected a few plants himself, upon arrival at Cooper Cr. with Brahe early in May 1861 (e.g. *Glinus oxygioides*, *Abutilon theophrasti*, *Eremophila duttonii* and *E. macdonnellii*).

DR W. F. WHEELER

Wheeler, as surgeon on A. W. Howitt's first relief contingent to search for Burke and Wills, reached Menindee on 3 Aug. (Beckler being still in camp there) and Stokes Ra. on 4 Sept. 1861. He also acted as botanical collector but gathered little or no material in New South Wales, apparently considering that Beckler had adequately worked the route from Swan Hill to the Queensland boundary. Wheeler's collection, representing at least 70 species, came from 'between Stokes Range and Cooper's Creek' (a distance of 50-60 m.); it included the types of several new species, viz: *Isotropis wheeleri*, *Euphorbia wheeleri*, *Leschenaultia divaricata*, *Scaevola patens* (= *S. depauperata* R.Br.) and *Gnephosis eriocarpa*.

He arrived back at the Pamamaroo depot near Menindee on 28 Oct., staying there with Vining, Sampson and Calcott to safeguard the stores while Howitt came on to Melbourne with the remainder of his party and King (sole survivor of Burke's small team that reached the Gulf). On 22 Nov., at Menindee, Dr Wheeler and his three companions tendered their joint resignation from Howitt's Contingent Exploration Party. But, after Howitt returned with a second expedition of 10 men on 1 Jan. 1862 (Dr J. P. Murray being the new surgeon and plant collector), Wheeler agreed to remain at the Darling R. camp and attend to an injured Sepoy camel-man. He stayed on for more than two months, reporting his arrival at Wentworth with the Sepoy on 24 Mar. 1862.

DR JAMES P. MURRAY

To join Howitt's second expedition in the dual capacity of surgeon and plant collector, Dr Murray had been granted 6 months' leave of absence, without pay, from the Staff of Melbourne Hospital. He met Howitt at Swan Hill on 14 Dec. 1861, and on New Year's Day 1862 they arrived at Pamamaroo depot where

Murray relieved Dr Wheeler of further botanical work, as the latter had in his turn taken over from Dr Beckler. This time the party proceeded N. via Mt Murchison near Wilcannia (19 Jan.), Kopayko Tank (27 Jan.), Torowoto Swamp (2 Feb.) and Stokes Ra. (16 Feb.), reaching Cooper Cr. depot on 2 Mar. Murray, who had done no collecting until then, was placed in charge of the depot camp; from its precincts he amassed the most comprehensive collection of plant specimens made on Cooper Cr. up to that time, viz. 96 species (including types of *Plagiosetum refractum*, *Acacia murrayana*, *Calotis porphyroglossa* and *Myrioccephalus rudallii*).

Except for one long excursion with Howitt—to the Diamantina R. above present Birdsville in July—Dr Murray remained at Cooper Cr. from 2 Mar. to 10 Oct. 1862. During those 7 months he established a vegetable garden, as a protection from scurvy, and when his party finally left the Creek depot they had not consumed all the vegetables raised. Howitt, in reporting (22/10/1862) to the Exploration Committee from Blanchewater Station, S.A., remarks that Dr Murray—

besides having always been zealous for the interests of the Expedition, has gained the perfect confidence of everyone by the skill and judgment he has shown in the treatment of such cases as came under his hands.

On 4 July Howitt and Murray travelled N. from Walkowinnie on Cooper Cr. (a day's march downstream from the depot) to Kyejeron Cr. and L. Apanpurra in the L. Goyder system, then NW. across Sturt's 'Stony Desert' to Goyder's Lagoon by 11 July. Three days later they reached the Diamantina R. near Salmonville, 14 m. upstream from Birdsville. In their records this watercourse is referred to as 'Wills's Creek', but it should not be confused with the present Wills Cr. between Boulia and Mt Isa. A week was spent in exploring up and down the Diamantina, across the Queensland border. At a point about 20 m. to the N. of Birdsville the very localized, rare *Acacia pence* was discovered and type material collected. Types of *Ptilotus murrayi* and *Zygophyllum howittii* were also secured in this region. The party followed almost the same route back, reaching Goyder's Lagoon on 25 July and Cooper Cr. depot on 2 Aug.

Murray's total plant collections embrace about 130 species. Combined with those of A. W. Howitt, they were worked up by F. Mueller who listed most of them, with localities, as a special section in his *Annual Report of the Government Botanist* (15 Apr. 1863), p. 16-18 entitled 'Enumeration of the plants collected by Dr J. Murray during Mr A. Howitt's Expedition into Central Australia in the year 1862'. A valuable collection of woods and some geological specimens were also brought back to Melbourne by Murray (with Howitt) on 27 Dec. His return to duty at the Melbourne Hospital was recorded at a meeting of the Committee of Management on 2 Jan. 1863, but at the Committee's meeting on 3 Mar. his retirement was noted. It is possible that the brevity of Murray's later association with Melbourne Hospital may be somehow connected with his exceeding the period of official leave by more than 6 months. He is not known to have done any subsequent botanical work, and the date of his death remains unknown. Murray received a salary of £300 for his year's work with Howitt.

ALFRED WILLIAM HOWITT

Howitt himself contributed a small number of specimens (representing some 25 species) from his 5 sorties in the north-eastern sector of South Australia during Mar.—Oct. 1862. These journeys from the Cooper Cr. base camp were chiefly ethnological and may be summarized briefly thus:

1. 5 Mar. to 2 Apr.—
Down Cooper and Strzelecki Cr. to Blanchewater, then NW. over stony plains to Baker's Station (?Appendrain Water), L. Hope, and back along Cooper Cr.
2. 12 Apr. to 1 May—
N. to the Coongie-L. Goyder area.
3. 17 May to late June—
SW. to Blanchewater and Paralana (Jacobs' Station between Mt Painter and the northern tip of L. Frome).
4. 3 July to 2 Aug.—
N. and W. to Sturt's 'Stony Desert', Goyder's Lagoon and along the Diamantina R. to the Birdsville region (with Dr Murray).
5. 16 Aug. to late Sept.—
To Blanchewater via L. Hope, then to Angipena Station in the heart of the northern Flinders Ra.
6. 10 Oct. to 8 Dec.—
From Cooper Cr. depot to Adelaide, via L. Hope, Blanchewater and Angipena, bringing the remains of Burke and Wills. During this last visit to Blanchewater, Howitt investigated the possibility of a direct route to the Darling via Grey Ra. and Sturt's Depot at Providence Cr., but found the country droughty and impracticable 'excepting immediately after heavy general rains'.

Chronological Arrangement of Dr H. Beckler's Collecting Places

(derived from his labels on specimens in the National Herbarium of Victoria)

Each locality is numbered and, where collections were made at the same place a second or third time, the numbers are suffixed by 'a' (up to and including Jan. 1861), 'b' (Feb.) or 'c' (Mar.-July 1861).

Date	Locality No.	Locality
1860		
Sept.		
14	1	Wakool R., N.S.W.
15	2	L. Yanga, N.S.W., 6-7 m. SE. of Balranald
17	3	Balranald
18	4	L. Paika ('Jin Sheepstation' of Beckler)
19-20	5	Tjerrikenkom ('Terikinkom' of Beckler)
21	6	Prungle House near Moonlight Tank ('Prangal' of Beckler, also 'undulating hills called Fargate Range')
24	7	Coles Waterhole
28	8	Arumpo House near Wall of China ('Aurumpo' of Beckler)
29	9	Arumpo House 14 m. NNW. to Garnpang ('Aurompo' to 'Conpang' of Beckler; 'Amompoo Company' of Mueller)
Oct.		
9	10	Bilbarka on Darling R., about 3 m. above Pooncarie or 'Macpherson's Station'
12	11	Near Tolarno on Darling ('Mr Cloud's Station' of Beckler)
14	12	20 m. downstream from Menindee
15	13	Menindee (sometimes rendered 'Meninville' by Bentham)
26, 28, 31	14a ₁	L. Pamamaroo, the base camp on Darling R. about 8 m. above Menindee ('Bamamero' and 'Bambamero' of Beckler; 'Bamancero', 'Banaroo' and 'Bambamero' of Mueller)
Nov.		
1-5	14a ₂	L. Pamamaroo

Date	Locality No.	Locality
5-7	15a	Scrope Ra. in vicinity of Kokriega Well or Burke's Cave, about 43 m. E. of Broken Hill ('Goginga Mountains' of Beckler; 'Goginya', 'Goyinga', 'Gozinga', 'Guginga', 'Yayinga', 'Yayinya', 'Yuyinga', 'Yuyingee', 'Toguya' etc. of Mueller and Benthams)
8, 21-22, 24 Dec.	14a	L. Pamamaroo ('clay flats on the Darling' etc.)
24	16	Noonthorangee Cr. ('Nandurungee' of Beckler; 'Naudthcrungee' and 'Nandirooga' of Mueller)
27	17a	Torowoto Swamp, about 44 m. ESE. of Milparinka ('Duroadoo' of Beckler; 'Duroodoo', 'Durandoo' or 'Tooroodoo' of Mueller and Benthams)
28	18	Torowoto to 'Nangarna' ('Nangavera' of Benthams)
29	19	'Nangawera to Yellowinchi', just N. of Mt Koonenberry
31	20	Mt Koonenberry, the focal point of Coturaundee Ra. ('Goning-beri' of Beckler; 'Goningbear' and 'Goningbery' of Benthams)
1861 Jan.		
1	21a	Wonominta and Noonthorangee Cr.
3	22a	Mootwingee ('Mootwanji' and 'Mutwanji' of Beckler; 'Mutanie Ranges' of Benthams)
Feb. 4-6	23	Nootumbulla Cr., 7-8 m. N. of Mootwingee ('Nothangbulla' of Beckler), also Bengoro Ra. ('Binguro' of Beckler)
8	21b	Noonthorangee and Wonominta Cr.
13-18	17b	Torowoto Swamp ('Duroadoo' of Beckler)
Mar. 3	17c	Torowoto Swamp
12, 17		No locality given, but perhaps 'Rat Point' of W. Wright
19, 22	24	Near Caryapundy Swamp and Puria Cr., almost on the Queensland border ('Cariapundi' of Beckler)
31	25	No locality given, but probably Kooliatoo Cr. between Queensland border and Bulloo L.—Beckler's most northerly collecting site
June 12	21c	Wonominta Cr. ('Wanamint' and 'Monument' of Benthams)
13	22c	Noonthorangee and Mootwingee
15-16	26	'Bodurga to Pilpa', just N. of Scrope Ra.
17	15c	Scrope Ra. ('Goginga Glen' of Beckler)
18-29	14c	L. Pamamaroo ('sand hills near the Darling')

List of Species and Collections

The present systematic arrangement follows that of Engler and Prantl in *Die Natürlichen Pflanzenfamilien* (1887-1902). Nomenclature has been brought up to date, and the names here adopted often differ from those cited in Benthams's *Flora Australiensis*.

B = Beckler (followed by number of collecting site—*vide* No. 1-26 in the Chronological Arrangement).

W = Wheeler (all from 'between Stokes Range and Cooper's Creek', unless otherwise stated).

M = Murray (all from Cooper Cr., near depot, unless otherwise stated).

H = Howitt (locality written in full—all in NE. South Australia).

Wright (name and locality written in full).

Species	Collector	Locality
PTERIDOPHYTA		
ADIANTACEAE		
<i>Cheilanthes distans</i> (R. Br.) Mett.	B	15a
<i>C. lasiophylla</i> Pichi-Sermolli	B	20

Species	Collector	Locality
ASPLENIACEAE		
<i>Pleurosorus rutifolius</i> (R. Br.) Fee	B	15a
MARSILEACEAE		
<i>Marsilea drummondii</i> A. Br.	M	Wills's Cr.
SPERMATOPHYTA—GYMNOSPERMAE		
CUPRESSACEAE		
<i>Callitris columellaris</i> F. Muell.	B	20
SPERMATOPHYTA—ANGIOSPERMAE		
GRAMINEAE		
<i>Tragus australionus</i> S. T. Blake	B W	14a ₃
<i>Neurachne mitchelliana</i> Nees	B	15a
<i>N. muuroi</i> F. Muell.	B	15a
<i>Panicum effusum</i> R. Br.	B	14a ₁ , 16a
<i>P. decompositum</i> R. Br.	M	
<i>P. ? whitei</i> J. M. Black	M	Not in Herb. Melb.
<i>Digitaria ammobila</i> (Benth.) D. K. Hughes	B	20
<i>D. brownii</i> (Roem. & Schult.) D. K. Hughes	B	15a
<i>Plagiosctum refractum</i> (F. Muell.) Benth.	M	TYPE
<i>Zygochloa paradoxa</i> (R. Br.) S. T. Blake	B W	14a ₃
<i>Amphipogon caricinus</i> F. Muell.	B	16
<i>Aristida contorta</i> F. Muell.	B ?M	16
<i>Stipa elegantissima</i> Labill.	B	10
<i>Eriachne helmsii</i> Domin	B	16
<i>Triraphis mollis</i> R. Br.	B M	15a
<i>Triodia scariosa</i> N. T. Burbridge	B	9
<i>Eragrostis australosica</i> (Steud.) C. E. Hubbard	B	16, 18
<i>E. setifolia</i> Nees	B	14a ₁
<i>E. dielsii</i> Pilger	B W	14a ₁
<i>Poa fax</i> J. H. Willis & A. B. Court	H B	No locality 9—TYPE
<i>Bromus arenarius</i> Labill.	B	14a ₁
<i>Chloris acicularis</i> Lindl.	B	14a ₃
<i>Astreblo pectinata</i> F. Muell.	B	20
<i>Dactyloctenium radicans</i> (R. Br.) Pal. Beauv.	M	
CYPERACEAE		
<i>Cyperus exaltatus</i> Retz.	B	?14—not in Herb. Melb.
<i>C. vaginatus</i> R. Br.	M	
<i>Eleocharis acuta</i> R. Br.	B	?14—not in Herb. Melb.
<i>E. pollens</i> (Benth.) S. T. Blake	B	17b, 17c
<i>Fimbristylis dichotoma</i> (L.) Vahl	B ?M	16
LILIACEAE		
<i>Lomandra leucocephala</i> (R. Br.) Ewart	B	9
<i>Tricoryne elatior</i> R. Br.	B	'Darling R. to Cooper's Cr. —not in Herb. Melb.
<i>Bulbine semibarbata</i> (R. Br.) Haw.	W	
AMARYLLIDACEAE		
<i>Crinum flaccidum</i> Herb.	M	
<i>Calostemma luteum</i> Sims	M	'S. of Wills's Cr.'

Species	Collector	Locality
CASUARINACEAE		
<i>Casuarina cristata</i> Miq.	B	14a ₂ , 14a ₃ , 15a
PROTEACEAE		
<i>Hakea leucoptera</i> R. Br.	B M	14a ₃ , 17a, 17b
<i>Grevillia pterosperma</i> F. Muell.	M	
<i>G. striata</i> R. Br.	B M	?14—'Darling Desert'
SANTALACEAE		
<i>Exocarpos aphyllus</i> R. Br.	B	14a ₂
<i>E. strictus</i> R. Br.	B	10
<i>Santalum acuminatum</i> (R. Br.) A.DC.	B	14a ₂
<i>S. lanceolatum</i> R. Br.	B M	15a
LORANTHACEAE		
<i>Lysiana exocarpi</i> (Behr) Van Tiegh.	M	
<i>Amyema linophylla</i> (Fenzl) Van Tiegh.	?	Not in Herb. Melb.
<i>A. preissii</i> (Miq.) Van Tiegh.	B M	20
<i>A. miraculosa</i> (Miq.) Van Tiegh.	B	20
<i>A. quandang</i> (Lindl.) Van Tiegh.	B M	15a
<i>Diplatia grandibracteata</i> (F. Muell.) Van Tiegh.	M	
POLYGONACEAE		
<i>Rumex brownii</i> Campd.	B	10
<i>Polygonum plebejum</i> R. Br.	W M	
<i>P. attenuatum</i> R. Br.	B W M	'near Darling'
<i>Muehlenbeckia cunninghamii</i> (Meissn.) F. Muell.)	B	20, 14c
CHENOPODIACEAE		
<i>Rhagodia gaudichaudiana</i> Moq.	B	14a ₁
<i>R. spinescens</i> R. Br.	B M	6, 15a
<i>R. nutans</i> R. Br.	B W M	15a, 17a, 17b, 26
<i>Chenopodium nitrariaceum</i> (F. Muell.) F. Muell. ex Benth.	B	14a ₃
<i>C. cristatum</i> (F. Muell.) F. Muell.	B	?14, 16
<i>C. carinatum</i> R. Br.	B	'Darling R.'—not in Melb. Herb.
<i>C. atriplicinum</i> (F. Muell.) F. Muell.	B	14a ₃ —'clay flats'
<i>C. auricomum</i> Lindl.	B	17a
<i>Dysphania littoralis</i> R. Br.	M	'S. of Wills's Cr.'
<i>Atriplex nummularia</i> Lindl.	B H	11, 14a ₁ , 14a ₃ , 25
<i>A. stipitata</i> Benth.	B H	'in the interior'
<i>A. hymenotheca</i> Moq.	B	'Darling Desert', 17b
<i>A. velutinella</i> F. Muell.	H	Cooper Cr.
<i>A. muelleri</i> Benth.	B	11, 14a ₁
<i>A. semibaccata</i> R. Br. var <i>microcarpa</i> (Benth.) Aellen	B	14a ₃ , 17a, 20
<i>A. eardleyae</i> Aellen	H	'in the interior'
	B	14a ₁ —TYPE of var.
	B	14a ₃

Species	Collector	Locality
<i>A. limbata</i> Benth.	B	11, 25
<i>A. inflata</i> F. Muell.	B	8
	H	'towards Cooper's Cr.'
<i>A. spongiosa</i> F. Muell. var. <i>holocarpa</i> (F. Muell.) J. M. Black	B	13, 18
	W	
<i>Bassia eriacantha</i> (F. Muell.) R. H. Anderson	B	'Darling Desert'—TYPE
<i>B. bicornis</i> (Lindl.) F. Muell.	B	19
	M	
<i>B. bicuspis</i> F. Muell.	W	
<i>B. stelligera</i> (F. Muell.) F. Muell.	B	14a ₂ , 14a ₃
<i>B. brachyptera</i> (F. Muell.) R. H. Anderson	B	8
	W	
	M	
<i>B. paradoxa</i> (R. Br.) F. Muell.	B	14a ₁ , ?'Rat Point' beyond Torowoto
<i>B. biflora</i> (R. Br.) F. Muell.	B	14a ₂
<i>B. obliquicuspis</i> R. H. Anderson	B	6
<i>B. lanicuspis</i> (F. Muell.) F. Muell.	B	19—TYPE
<i>Babbagia dipterocarpa</i> F. Muell.	W	
	M	
<i>Kochia lobiflora</i> F. Muell.	B	14a ₁ , 14a ₂ —TYPE
<i>K. pyramidata</i> Benth.	B	6, 17a, 14c
<i>K. eriantha</i> F. Muell.	W	
<i>K. appressa</i> Benth.	B	19
	M	
<i>K. tomentosa</i> (Moq.) F. Muell.	B	15a, 15c, 24
var. <i>tenuifolia</i> F. Muell.	M	
<i>K. sedifolia</i> F. Muell.	B	20
<i>K. aphylla</i> R. Br.	B	4, ?'Rat Point' beyond Torowoto
<i>K. triptera</i> Benth.	B	26, 14c—TYPE
<i>Salsola kali</i> L.	B	13, 19, 24
	W	
	M	
<i>Enchylaena tomentosa</i> R. Br.	B	15a, 14c
	M	
<i>Threlkeldia salsuginosa</i> (F. Muell.) Benth.	M	
<i>Arthrocnemum leiostachyum</i> (Benth.) Paulsen	H	Kyejeron Cr.
<i>Pachycornia tenuis</i> (Benth.) J. M. Black	B	8—TYPE
	H	'in the interior'—TYPE
AMARANTHACEAE		
<i>Ptilotus obovatus</i> (Gaudich.) F. Muell.	B	20, 17b
	H	Flinders Ra.
<i>P. alopecuroides</i> (Lindl.) F. Muell.	B	14a ₃ , 16, 20
	M	
<i>P. murrayi</i> F. Muell.	M	'towards Wills's Cr.'—TYPE
<i>P. latifolius</i> R. Br.	M	'between Cooper's Cr. and Stony Desert'
<i>Alternanthera nodiflora</i> R. Br.	B	14a ₁ , 14a ₃
<i>A. denticulata</i> R. Br.	M	'S. of Wills's Cr.'
NYCTAGINACEAE		
<i>Boerhavia diffusa</i> L.	B	19
	M	
GYROSTEMONACEAE		
<i>Codonocarpus cotinifolius</i> (Desf.) F. Muell.	B	16, 21b, 26
FICOIDACEAE		
<i>Disphyma australe</i> (Soland.) J. M. Black	B	5

Species	Collector	Locality
<i>Tetragonia tetragonioides</i> (Pallas) O. Kuntze	B	13
<i>Gunnerops quadrifida</i> (F. Muell.) Pax	B	18, 19
<i>Trianthema decandra</i> L.	M	'between Cooper's and Wills's Cr.'
<i>Glinus orygioides</i> F. Muell.	B	24
<i>Mollugo cerviana</i> (L.) Ser.	Wright	Cooper Cr.
	B	22a
PORTULACACEAE		
<i>Portulaca oleracea</i> L.	M	
<i>P. filifolia</i> F. Muell.	M	
<i>Calandrinia remota</i> J. M. Black	B	17a
<i>C. balonnensis</i> Lindl.	M	'S. of Wills's Cr.'
<i>C. volubilis</i> Benth.	B	14a, 14a, 15a
<i>C. calyptrata</i> Hook. f.	B	2
<i>C. pumila</i> F. Muell.	B	19
CARYOPHYLLACEAE		
<i>Spergularia rubra</i> (L.) J. & C. Presl	B	'Darling R.'—not in Herb. Melb.
CAPPARIDACEAE		
<i>Capparis mitchellii</i> Lindl.	B	'100-mile Cr.'
	M	
CRUCIFERAE		
<i>Blennodia trisepta</i> (F. Muell.) Benth.	B	4, 13
<i>B. nasturtium</i> (F. Muell.) Druce	B	?14
<i>B. blennodioides</i> (F. Muell.) Druce	B	8, 22a, 26, 14c
	W	
	M	
<i>B. cardaminoides</i> (F. Muell.) Benth.	B	?14—TYPE from 'Darling R.'
<i>B. canescens</i> R. Br.	B	?14
<i>B. eremigera</i> (F. Muell.) Benth.	B	14a—TYPE
<i>Alyssum linifolium</i> Steph. ex Willd.	B	'near Darling'
<i>Lepidium papillosum</i> F. Muell.	W	
<i>Stenopetalum velutinum</i> F. Muell.	W	
<i>S. nutans</i> F. Muell.	W	TYPE
CRASSULACEAE		
<i>Crassula sieberiana</i> (Schultes) Ostenf.	B	15a
PITTOSPORACEAE		
<i>Pittosporum phillyroides</i> DC.	B	15a
MIMOSACEAE		
<i>Acacia peuce</i> F. Muell.	M	'N. of Wills's Cr.'—TYPE
<i>A. microcarpa</i> F. Muell.	B	?14 on 'plains of Darling R.'
<i>A. brachybotrya</i> Benth.	B	3, 9
<i>A. victoriac</i> Benth.	B	14a, 14a
<i>A. murrayana</i> F. Muell.	M	TYPE
<i>A. salicina</i> Lindl.	B	17b, 25, 21c, 22c, 26
	M	
<i>A. sp.</i> (aff. <i>A. pycnantha</i>)	B	26
<i>A. tetragonophylla</i> F. Muell.	B	15a
	M	
<i>A. homalophylla</i> A. Cunn. ex Benth.	B	5
	M	
<i>A. stenophylla</i> A. Cunn. ex Benth.	B	17c
	W	

Species	Collector	Locality
<i>A. oswoldii</i> F. Muell.	B M	15a, 14a _s
<i>A. rigens</i> A. Cunn. ex G. Don	B	9
<i>A. ancura</i> F. Muell.	M	No locality
<i>A. brachystachya</i> Benth.	B	22a—TYPE
<i>A. farnesiana</i> Willd.	M	
CAESALPINIACEAE		
<i>Cassia pleurocarpa</i> F. Muell.	B	20
<i>C. pruinosa</i> F. Muell.	W	
<i>C. circinnata</i> Benth. in Mitch.	B	20, 21a, 21c, 26
<i>C. phyllodinea</i> R. Br.	B M	15a, 19
<i>C. artemisioides</i> Gaudich.	B	15a, 19, 20, 22c, 26
<i>C. sturtii</i> R. Br.	B	5, 8, 10, 14a _s , 14c, 15a, 15c, 20, 22c, 26
	W	
<i>C. desolata</i> F. Muell.	M B	15a, 20, 26
	M	
<i>C. eremophila</i> A. Cunn. ex Vog. var. <i>platypoda</i> Benth.	M B	20, 24
<i>Petalostylis labicheoides</i> R. Br.	B	23
<i>Bauhinia carronii</i> F. Muell.	M	
PAPILIONACEAE		
<i>Eutaxia microphylla</i> (R. Br.) J. M. Black	B	9
<i>Isotropis wheeleri</i> F. Muell. ex Benth.	W	TYPE
<i>Bossiaea walkeri</i> F. Muell.	B	'towards Barrier Ra.'
<i>Templetonia egena</i> (F. Muell.) Benth.	B	3
<i>Crotalaria cunninghamii</i> R. Br.	W M	Near Cooper Cr. 'within 50 m. of Stony Desert'
<i>C. eremaea</i> F. Muell.	B W	17a
<i>Trigonella suavissima</i> Lindl.	B M	14a _s 'flooded ground N. of Stony Desert'
<i>Lotus cruentus</i> A. B. Court	B M	14a ₂
<i>Psoralea patens</i> Lindl.	B M	14a ₁
<i>P. eriantha</i> Benth.	B	14a ₁
<i>Sesbania aculeata</i> Poir.	M	
<i>Chianthus formosus</i> (G. Don) N. Ford & J. W. Vickery	H B	'Flinders Ra.'
<i>Swainsona greyana</i> Lindl.	B	11, 14a ₂
<i>S. oligophylla</i> F. Muell.	B W	9—TYPE, 20, 21b
<i>S. oroboides</i> F. Muell.	H	'in the interior'
<i>S. laxa</i> R. Br.	B	14a ₁
<i>S. stipularis</i> F. Muell.	B W	14c
	H	Flinders Ra.
<i>S. fissimontana</i> J. M. Black	B	20
<i>S. phacoides</i> Benth.	B M	16, 19 'S. of Wills's Cr.'
<i>S. microphylla</i> A. Gray	B	14a ₁
<i>Glycine sericca</i> (F. Muell.) Benth.	W	
<i>G. clandestina</i> J. Wendl.	B	15a

Species	Collector	Locality
<i>Rhynchosia minima</i> (L.) DC.	B	20
<i>Vigna lanceolata</i> Benth.	M	'S. of Wills's Cr.'
ZYGOPHYLLACEAE		
<i>Zygophyllum ammophilum</i> F. Muell.	B	14as
<i>Z. fruticosum</i> DC.	B	5
<i>Z. howittii</i> F. Muell.	M	'near Wills's Cr.'—TYPE
<i>Tribulus terrestris</i> L.	M	
<i>T. hystrix</i> R. Br.	M	
RUTACEAE		
<i>Geijera parviflora</i> Lindl.	B	'near Darling'
<i>Flindersia maculosa</i> (Lindl.) F. Muell.	B	20
MELIACEAE		
<i>Owenia acidula</i> F. Muell.	B	17a
	M	
EUPHORBIACEAE		
<i>Phyllanthus rigens</i> Muell.-Arg.	B	22a—TYPE
<i>P. ramosissimus</i> (F. Muell.) Muell.-Arg.	B	15a
<i>P. trachyspermus</i> F. Muell.	M	
<i>Adriana hookeri</i> (F. Muell.) Muell.-Arg.	M	
<i>Euphorbia australis</i> Boiss.	B	'near Barrier Ra.'—TYPE
		<i>E. erythrantha</i> F. Muell.
<i>E. drummondii</i> Boiss.	B	20
	M	'interior'
<i>E. wheeleri</i> Baill.	W	TYPE
<i>E. eremophila</i> A. Cunn. in Mitch.	B	'near Darling'
	W	
	H	Cooper Cr.
SAPINDACEAE		
<i>Atalaya hemiglaucula</i> F. Muell.	B	17b, 24
	W	
	H	Cooper Cr.
<i>Dodonaea cuneata</i> Rudge	B	22a
<i>D. attenuata</i> A. Cunn. in Field	B	14a ₁ , 20, 22a
	W	
<i>D. lobulata</i> F. Muell.	B	15a, 22a
MALVACEAE		
<i>Lavatera plebeja</i> Sims	B	8
	M	Wills's Cr.
<i>Malvastrum spicatum</i> (L.) A. Gray	B	15a, 19
	M	
<i>Sida corrugata</i> Lindl.	B	19
	M	
	H	Flinders Ra.
<i>S. goniocarpa</i> (F. Muell.) Domin	B	19—TYPE
<i>S. fibulifera</i> Lindl.	B	15a, 20
	V	
<i>S. trichopoda</i> F. Muell.	B	14as, 15a
<i>S. pedunculata</i> A. Cunn. ex Domin	B	20
<i>S. sp.</i>	B	19
<i>S. intricata</i> F. Muell.	B	6, 14a ₁ , 18
<i>S. petrophila</i> F. Muell.	B	15a
	W	
	H	Angipena Station

Species	Collector	Locality
<i>Abutilon leucopetalum</i> (F. Muell.) F. Muell. ex Benth.	B W H B W	20 Flinders Ra. 15a, 16, 18, 20
<i>A. otocarpum</i> F. Muell.	Wright	Cooper Cr.
<i>A. theophrasti</i> Medic.	B	15a
<i>A. halophilum</i> F. Muell.	W B	
<i>A. fraseri</i> Hook. [var. <i>parviflora</i> Benth.	B	20
<i>Hibiscus brachysiphonius</i> F. Muell.	B	15a—not in Herb. Melb.
<i>H. sturtii</i> Hook. [var. <i>grandiflora</i> Benth.	B	20—TYPE of var.
<i>H. krichauffianus</i> F. Muell.	B ?M	20 Cooper Cr.
<i>Gossypium sturtianum</i> J. H. Willis	B H	22a Flinders Ra.
ELATINACEAE		
<i>Bergia trimera</i> Fisch. & Mey.	M	
FRANKENIACEAE		
<i>Frankenia foliosa</i> J. M. Black	B M	20
THYMELAEACEAE		
<i>Pimelea simplex</i> F. Muell.	B	15a
<i>P. microcephala</i> R. Br.	B	14a ₁ , 17a, 21c
LYTHRACEAE		
<i>Lythrum hyssopifolia</i> L.	B	17a
<i>Ammannia multiflora</i> Roxb.	B	17c
MYRTACEAE		
<i>Eucalyptus largiflorens</i> F. Muell.	B	14a ₁ , 14a ₂ , 14a ₃
<i>E. microtheca</i> F. Muell.	B M	17b, 24
<i>E. dumosa</i> A. Cunn. ex Schauer	B	7
<i>E. incrassata</i> Labill.	B	9
<i>E. camaldulensis</i> Dehnh.	B W H	10, 14a ₂ Cooper Cr.
<i>E. oleosa</i> F. Muell.	B	5
<i>E. gracilis</i> F. Muell.	B	5, 7
<i>Leptospermum laevigatum</i> (Gaertn.) F. Muell.		
var. <i>minus</i> F. Muell.	B	9
<i>Callistemon brachyandrus</i> Lindl.	B	22c
ONAGRACEAE		
<i>Jussieua repens</i> L.	W M	Not in Herb. Melb.
HALORAGACEAE		
<i>Haloragis heterophylla</i> Brongn.	B	14a ₁
<i>H. glauca</i> Lindl.	M	
<i>Myriophyllum verrucosum</i> Lindl.	B M	20
UMBELLIFERAE		
<i>Hydrocotyle trachycarpa</i> F. Muell.	B	10, 17b
<i>Trachymene glaucifolia</i> (F. Muell.) Benth.	B H	17a Flinders Ra.
<i>Daucus glochidiatus</i> (Labill.) Fisch. et al.	B	14a ₂

Species	Collector	Locality
OLEACEAE		
<i>Jasminum lineare</i> R. Br.	B	15a
LOGANIACEAE		
<i>Logania nuda</i> F. Muell.	B	'desert of Murray and Darling'—not in Herb. Melb.
GENTIANACEAE		
<i>Centaurium spicatum</i> (L.) Druce	B	14a ₁ , 14a ₂
APOCYNACEAE		
<i>Parsonsia eucalyptophylla</i> F. Muell.	B	20, 22a—TYPE
ASCLEPIADACEAE		
<i>Sarcostemma australe</i> R. Br.	B	20
<i>Cynanchum floribundum</i> R. Br.	B	15a
<i>Marsdenia australis</i> (R. Br.) Druce	B W	20
CONVOLVULACEAE		
<i>Convolvulus erubescens</i> Sims	B	14a ₁ , 14a ₂
<i>Cressa cretica</i> L.	B	'Darling R.', 17c
<i>Evolvulus alsinoides</i> L.	M	
BORAGINACEAE		
<i>Halgania cyanea</i> Lindl.	B	9
<i>Coldenia procumbens</i> L.	M	
<i>Heliotropium ovalifolium</i> Forsk.	M	
<i>H. flaginoides</i> Benth.	H	Cooper Cr.
<i>Trichodesma zeylanicum</i> (Burm.) R. Br.	B W	20
<i>Omphalolappula concava</i> (F. Muell.) Brand	M B W	'Darling R.'
VERBENACEAE		
<i>Verbena officinalis</i> L.	B	14a ₁
LABIATAE		
<i>Ajuga australis</i> R. Br.	B	2
<i>Teucrium racemosum</i> R. Br.	B W M	12, 14a ₁
<i>Mentha australis</i> R. Br.	B M	14a ₂
<i>Prostanthra striatiflora</i> F. Muell.	B W	15a
SOLANACEAE		
<i>Solanum nigrum</i> L.	B	'near Darling'
<i>S. parvifolium</i> R. Br.	B	15a—TYPE <i>S. leptophyllum</i> F. Muell.
<i>S. esuriale</i> Lindl.	B W M	14a ₂ , 15a, 16, 20
<i>S. chenopodium</i> F. Muell.	B M	14a ₂ , 17a, 20
<i>S. sturtianum</i> F. Muell.	M H	'S. of Wills's Cr.'
<i>S. lacunarium</i> F. Muell.	B	Flinders Ra.
<i>S. petrophilum</i> F. Muell.	B H	10 21a, 22a, 26 Flinders Ra.

Species	Collector	Locality
<i>S. ellipticum</i> R. Br.	B	15a, 20
	M	
<i>Nicotiana velutina</i> H. Wheeler	B	14a _s
	W	
	M	Wills's Cr.
<i>Duboisia hopwoodii</i> F. Muell.	B	8—very rare
SCROPHULARIACEAE		
<i>Mimulus gracilis</i> R. Br.	B	17b, 17c, 21c, 15c
<i>M. prostratus</i> Benth.	H	'S. of Wills's Cr.'
<i>Morgania floribunda</i> Benth.	B	10, 12
	W	
	M	'between Wills's Cr. and Stony Desert'
	Wright	Cooper Cr.
PEDALIACEAE		
<i>Josephinia eugeniae</i> F. Muell.	M	'Cooper's Cr. at the N. branch', Kyejeron
ACANTHACEAE		
<i>Justicia procumbens</i> L.	B	15a, 20
	W	
	M	Flinders Ra.
MYOPORACEAE		
<i>Myoporum montanum</i> R. Br.	B	26
	M	
<i>M. deserti</i> A. Cunn. ex Benth.	B	14a _s , 14c
<i>M. platycarpum</i> R. Br.	B	14a _s , 15a, 21a
<i>Eremophila oppositifolia</i> R. Br.	B	15a
<i>E. ?paisleyi</i> F. Muell.	B	14a ₁
<i>E. sturtii</i> R. Br.	B	11
	W	
<i>E. latrobei</i> F. Muell.	B	20
	W	
	M	
<i>E. longifolia</i> (R. Br.) F. Muell.	B	14a ₁ , 22a, 26
	M	
<i>E. divaricata</i> (F. Muell.) F. Muell.	B	13
<i>E. freelingii</i> F. Muell.	W	
	M	
<i>E. goodwinii</i> F. Muell.	B	22c, 26
	W	
<i>E. scoparia</i> (R. Br.) F. Muell.	B	21b
	M	
<i>E. bignoniiflora</i> (Benth.) F. Muell.	B	14a _s
<i>E. polyclada</i> (F. Muell.) F. Muell.	B	14a ₁ , 14a _s , 14a _s
<i>E. duttonii</i> F. Muell.	B	26
	Wright	Cooper Cr.
<i>E. maculata</i> (Ker) F. Muell.	B	10, 14a ₁ , 17c
	W	
	M	
<i>E. latifolia</i> F. Muell.	B	15a
<i>E. glabra</i> (R. Br.) Ostenf.	B	9, 15a
<i>E. dalyana</i> F. Muell.	W	TYPE—not in Herb. Melb.
<i>E. macdonnellii</i> F. Muell.	M	Cooper Cr., 'S. of Wills's Cr.'
	Wright	Cooper Cr.
PLANTAGINACEAE		
<i>Plantago pritzelii</i> Pilger	B	6, 14a _s , 15a
	W	

Species	Collector	Locality
RUBIACEAE		
<i>Synaptantha tillaeacea</i> (F. Muell.) Hook. f.	B M	17a—TYPE Cooper & Wills's Cr.— TYPE
<i>Dentella pulvinata</i> Airy-Shaw	M	
<i>Galium geminifolium</i> F. Muell.	B	14a ₂
CUCURBITACEAE		
<i>Cucumis chate</i> Hasselq.	M	Cooper & Wills's Cr.
CAMPANULACEAE		
<i>Cephalostigma fluminense</i> J. M. Black	B W M	10, 11, 14a ₁
LOBELIACEAE		
<i>Isotoma petraea</i> F. Muell.	B W	15a
GOODENIACEAE		
<i>Goodenia geniculata</i> R. Br.	B	9
<i>G. cycloptera</i> R. Br.	B W	16
<i>G. pinnatifida</i> Schlechtendal	B H	3, 10 Cooper Cr.
<i>G. glauca</i> F. Muell.	?H	'L. Torrens to Wills's & Cooper's Cr.'—not in Herb. Melb.
<i>var. glandulosa</i> Benth.	B	15a—TYPE of var.
<i>G. heteromera</i> F. Muell.	B	11, 12, 14a ₁ , 14a ₃
<i>Velleia paradoxa</i> R. Br.	B	15a
<i>Leschenaultia divaricata</i> F. Muell.	W M	Cooper Cr.—TYPE
<i>Scaevola spinescens</i> R. Br.	B	15a
<i>S. depauperata</i> R. Br.	W	Cooper Cr.—TYPE S.
<i>S. ovalifolia</i> R. Br.	B M	<i>patens</i> F. Muell. 20
COMPOSITAE		
<i>Brachycome melanocarpa</i> Sond. & F. Muell.	B	12, 13
<i>B. lineariloba</i> (DC.) Druce	B	14c
<i>B. leptocarpa</i> F. Muell.	B	'Darling R.'
<i>B. exilis</i> Sond.	B	14a ₁
<i>Minuria leptophylla</i> DC.	B W	15a, 18
<i>M. cunninghamii</i> (DC.) Benth.	B	13, 15a
<i>M. integerrima</i> (DC.) Benth.	B M	17b
<i>M. denticulata</i> (DC.) Benth.	B	? 'Rat Point' beyond Toro- woto, 24
<i>Calotis cuneifolia</i> R. Br.	B	20, 17b
<i>C. erinacea</i> Steetz	W	
<i>var. parviflora</i> Benth.	B	17a—TYPE of var.
<i>C. scabiosifolia</i> Sond. & F. Muell.	B	14a ₁
<i>C. scapigera</i> Hook.	B	12
<i>C. multicaulis</i> (Turcz.) Druce	B	13, 15a, 20
<i>C. porphyroglossa</i> F. Muell.	M	TYPE
<i>C. hispidula</i> (F. Muell.) F. Muell.	B W	4, 15a
<i>Vittadinia triloba</i> (Gaudich.) DC.	M B	'N. of Stony Desert' 20

Species	Collector	Locality
<i>V. pterochaeta</i> (F. Muell.) J. M. Black	B	'Darling Desert'—not in Herb. Melb.
<i>Podocoma cuneifolia</i> R. Br.	B	20
<i>Olearia subspicata</i> (Hook.) Benth.	B	9
<i>O. lepidophylla</i> (Pers.) Benth.	B	'Darling R.'
<i>O. pimeleoides</i> (DC.) Benth.	B	14a ₂
<i>O. magniflora</i> F. Muell.	B	2—TYPE
<i>O. muelleri</i> (Sond.) Benth.	B	3, 14a ₁
<i>O. decurrens</i> (DC.) Benth.	B	15a
<i>Siegesbeckia orientalis</i> L.	B	15a
<i>Centipeda cunninghamii</i> (DC.) A. Br. & Aschers.	B	10, 14a ₁ , 21c
	M	
<i>Isoetes graminifolia</i> Turcz	B	14c
<i>Elachanthus pusillus</i> F. Muell.	B	'Darling R.'
<i>Pluchea rubelliflora</i> (F. Muell.) J. M. Black	B	'Darling R.', 23
<i>Cratystylis conocephala</i> (F. Muell.) S. Le M. Moore	B	'Darling R.'—not in Herb. Melb.
<i>Epaltes cunninghamii</i> (Hook.) Benth.	B	17b
	W	
<i>E. australis</i> Less.	M	
<i>Gnaphalium involucratum</i> Forst. f.	B	'Darling R.'—not in Herb. Melb.
<i>G. indicum</i> L.	B	'Darling R.'—not in Herb. Melb.
<i>Cassinia laevis</i> R. Br.	B	22a, 26
<i>Helipterum floribundum</i> DC.	B	14a ₂
	W	
	M	'S. of Wills's Cr.'
<i>H. polygalifolium</i> DC.	B	'Darling R.'—not in Herb. Melb.
<i>H. cotula</i> (Benth.) DC.	B	14a ₁ —TYPE <i>H. semisterile</i> F. Muell.
<i>H. hyalospermum</i> F. Muell. ex Benth.	B	'Darling R.'
<i>H. corymbiflorum</i> Schlechtendal	B	3
<i>H. strictum</i> (Lindl.) Benth.	B	15a
	W	
<i>H. pterochaetum</i> (F. Muell.) Benth.	B	20
<i>H. moschatum</i> (A. Cunn.) Benth.	B	10, 14c
	W	
	M	'S. of Wills's Cr.'
<i>Ixiolaena leptolepis</i> (DC.) Benth.	B	14a ₃
<i>I. tomentosa</i> Sond. & F. Muell.	B	20
	H	Flinders Ra.
<i>Helichrysum semifertile</i> F. Muell.	B	15a, 14a ₃
	W	
	M	'S. of Wills's Cr.'
<i>H. apiculatum</i> (Labill.) DC.	M	
<i>H. ambiguum</i> Turcz.	B	15a, 20—TYPE <i>H. semicalvum</i> F. Muell.
<i>H. podolepideum</i> F. Muell.	B	20, 21a
<i>Acanthocladium dockeri</i> F. Muell.	B	14a ₁ —TYPE
<i>Leptorhynchus waitzia</i> Sond.	B	6
<i>Millotia myosotidifolia</i> Steetz	B	9
<i>M. greavesii</i> F. Muell.	B	'Sandhills near Darling'—TYPE
	W	
<i>Rutidosia helichrysoides</i> DC.	B	'Darling R.', 18, 20, 17b, 22c, 26
	M	Cooper Cr., 'S. of Wills's Cr.'

Species	Collector	Locality
<i>Podolepis canescens</i> A. Cunn. ex DC.	B	20
<i>P. capillaris</i> (Steetz) Diels	B	9
	W	
<i>Myriocephalus stuartii</i> (F. Muell. & Sond. ex Sond.) Benth.	B	10
	W	
	M	'S. of Wills's Cr.'
<i>M. rudallii</i> (F. Muell.) Benth.	M	TYPE
<i>Angianthus brachypappus</i> F. Muell.	B	5
<i>A. strictus</i> (Steetz) Benth.	B	'between Murray & Darling'—not in Herb. Melb.
<i>A. pusillus</i> (Benth.) Benth.	B	9, 14a ₁
<i>Gnephosis skirrophora</i> (Sond. & F. Muell.) Benth.	B	14a ₁
<i>G. gnephosioides</i> (F. Muell.) Druce	B	14a ₁ —TYPE
<i>G. eriocarpa</i> (F. Muell.) Benth.	W	TYPE
<i>Eriochlamys behrii</i> Sond. & F. Muell.	B	8, 17a
	W	
<i>Calocephalus platycephalus</i> (F. Muell.) Benth.	B	24—TYPE
<i>Gnaphalodes uliginosum</i> A. Gray	B	5
<i>Craspedia pleiocephala</i> F. Muell.	B	12
	W	
<i>C. chrysanthia</i> (Schlechtendal) Benth.	B	12
	M	
<i>Senecio gregorii</i> F. Muell.	B	9
	M	'S. of Wills's Cr.'
<i>S. glossanthus</i> (Sond.) Belcher	B	'Darling R.'
	W	
<i>S. magnificus</i> F. Muell.	H	Flinders Ra.
<i>S. lautus</i> Forst. f. ex Willd.	B	'Darling R.'
	W	
<i>S. cunninghamii</i> DC.	B	10, 14a ₂
	M	
<i>Picris hieracioides</i> L.	B	'Darling R. clay flats'

Acknowledgement

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SOME CRETACEOUS AND TERTIARY MICROFOSSILS FROM WESTERN AUSTRALIA

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Abstract

4 new genera and 10 new species of microfossils of uncertain affinity from Australian Cretaceous and Eocene sediments are described.

Introduction

During the course of a palynological examination of Cretaceous sediments in Western Australia a number of small microfossils of unknown nature and affinity have been found. Although it has not been possible to place these fossils taxonomically or even to throw light on their origin and significance, they are interesting in themselves and for this reason are deemed worthy of record and description. A few of them may have been, as Churchill (1960) has suggested for one of the forms to be mentioned herein, the aplanospores of Algae but others almost certainly do not fall into this category.

The deposits in which the microfossils occur were subjected to Schulze's solution after a pre-treatment with hydrofluoric acid and subsequently to alkali. It is evident, therefore, that the composition of the walls of the microfossils in question must have been very similar to that of the fossil dinoflagellates, hystrichospheres, microspores and cuticles with which they are associated.

The figured specimens are in the palaeontological collection of the National Museum of Victoria. Numbers prefaced by the letter P are registered numbers in that collection.

Systematic Descriptions

[INCERTAE SEDIS]

Genus *Lecaniella* gen. nov.

DESCRIPTION: Shell roughly saucer-shaped, one-layered, variously patterned on the outer surface.

TYPE SPECIES: *Lecaniella margostrata* sp. nov.

Lecaniella margostrata sp. nov.

(Pl. XXXVII, fig. 16, 17; holotype fig. 16; P21291)

AGE AND OCCURRENCE: Probably Albian: Power House Bore, near Perth, W.A. at 478 ft. ?Upper Albian-Cenomanian: Fremantle, W.A. Traffic Bridge No. 5 Bore at 100 ft.

DESCRIPTION: Shell small, rather deeply saucer-shaped, relatively thick-walled, the outer surface delimited by the sculptural pattern into a central and marginal zone. The central zone is ornamented with a shallow, wide-meshed reticulum the

muri of which are straight or wavy, evenly or unevenly thickened and, occasionally, incomplete. The marginal zone is characterized by the development of closely arranged radial thickenings which extend from the limits of the central zone to the rim of the shell.

DIMENSIONS: Holotype—diameter $c. 42\mu$. Range—diameter $30-42\mu$.

Lecaniella dictyota sp. nov.

(Pl. XXXVII, fig. 18-20; holotype fig. 18; P21457)

AGE AND OCCURRENCE: ?Albian-Aptian: Jandakot Bore, near Perth, W.A. at 450 ft; Rakich's Bore, Caversham near Perth, at 350-355 ft. Probably Albian: Power House Bore, Perth at 478 ft. ?Upper Albian-Cenomanian: Attadale Bore, near Perth at 354 ft; Fremantle Traffic Bridge No. 5 Bore at 100 ft; Subiaco Bore (Light sample) at 358 ft.

DESCRIPTION: Shell rather flat, relatively large, the greater portion of the surface ornamented with a shallow reticulum the small to large meshes of which are polygonal in shape and the muri smooth straight or curved. At the rim the muri of adjoining meshes are radially directed so that the enclosed meshes are approximately rectangular in shape and collectively give the appearance of a marginal 'layer'.

DIMENSIONS: Holotype—diameter 82μ . Range—diameter $62-90\mu$.

COMMENTS: In one preparation, two examples of *S. dictyota* are lying in close juxtaposition to one another as if they were the two halves of one individual. This suggestion is further enhanced by the fact that the patterned surface of one 'half' is best seen at high focus, in the other at low focus. Moreover, the two specimens are of the same size and have the same type of pattern.

Such an idea would be conformable with the mode of opening by median split in some Chlorophyceae, e.g. *Phacotus*.

Genus *Schizocystia* gen. nov.

DESCRIPTION: Shell with almost straight to deeply convex sides without appendages or horns, separating into two approximately equal halves along a straight line. Surface of shell patterned or otherwise.

TYPE SPECIES: *Schizocystia rugosa* sp. nov.

Schizocystia rugosa sp. nov.

(Pl. XXXVII, fig. 11, 12; holotype fig. 11; P21465)

AGE AND OCCURRENCE: ?Upper Albian-Cenomanian: Fremantle Traffic Bridge Bore No. 5 at 100 ft.

DESCRIPTION: Sides of shell deeply concave, wall $3-4\mu$ thick with strongly marked wavy ridges that run transversely or obliquely across the surface.

DIMENSIONS: Holotype— 72μ long, 52μ broad, width in middle 38μ . Paratype (fig. 12)—width 58μ .

Schizocystia laevigata sp. nov.

(Pl. XXXVII, fig. 13, 14; holotype fig. 13; P21466)

AGE AND OCCURRENCE: ?Upper Albian-Cenomanian: Subiaco Bore, Perth, W.A. at 358 ft (dark sample).

DESCRIPTION: Shell with slightly to deeply concave sides, walls *c.* 3μ thick with a low and lightly indicated vermiculate pattern.

DIMENSIONS: Holotype— $42 \times 56\mu$. Paratype (fig. 14)—width 83μ , median length 57μ .

COMMENTS: We have no evidence, other than general appearance, that the two specimens shown in Pl. XXXVII, fig. 13, 14 are complete and incomplete examples of one species. However, the centrally placed slit in the complete specimen (fig. 14) is very suggestive.

Halophoridia gen. nov.

DESCRIPTION: Shell disc-shaped, partially filled with a roughly hour-glass-shaped capsule. Wall of shell thin and delicate; wall of capsule untabulated.

TYPE SPECIES: *Halophoridia xena* sp. nov.

Halophoridia xena sp. nov.

(Pl. XXXVII, fig. 6-8; holotype fig. 6; P21463)

AGE AND OCCURRENCE: Probably Albian: Power House Bore at 478 ft. ?Upper Albian-Cenomanian: Fremantle Traffic Bridge Bore No. 5 at 100 ft N. of Gingin seismic shot hole B1 West Australian Petroleum Pty Ltd at 210, 220 ft.

DESCRIPTION: Shell circular to sub-circular in outline, wall membranous, thin, hyaline and delicate (sometimes partially destroyed) with a finely dotted surface. Capsule slightly longer than broad, untabulated, roughly hour-glass-shaped, the side walls deeply concave, the end walls straight or slightly concave one of the angles at the 'anterior' end being more prominent than the other three. Wall of capsule moderately thick and smooth, an opening has not been observed.

DIMENSIONS: Holotype—overall, 45μ long, 40μ broad; capsule $30 \times 25\mu$. Range—overall, $37\text{--}53\mu$ long; $32\text{--}52\mu$ broad.

COMMENTS: If the above interpretation of *Halophoridia xena* is correct, a comparison between it and the two Cretaceous genera *Diplotesta* and *Trigonopyxidina* Cookson and Eisenack 1960(a) (b) at once suggests itself. On this basis the shells of all three agree in being partially filled by an inner capsule but whereas in *Diplotesta* and *Trigonopyxidina* the shell membrane is relatively firm and cleanly outlined, in *H. xena* it is diaphanous, more indefinite in outline, and readily destroyed.

In the three figured examples of *H. xena*, a concave area suggestive of an opening can be seen at the so-styled anterior end of the shell. However, whether this represents a natural opening or is an artificial break cannot be decided at present. In *Diplotesta* and *Trigonopyxidina*, the opening of the shell is effected by the removal of the end wall of one of the ends of the shell.

Genus *Horologinella* gen. nov.

DESCRIPTION: Shell small, slightly biconvex, roughly hour-glass-shaped with or without an opening at one end, surface with or without fields, smooth or sculptured.

TYPE SPECIES: *Horologinella lineata* sp. nov.

COMMENTS: The genus *Horologinella* is intended purely as a form genus without implication of any natural affinity between the individual types included in it. The two specimens from Carboniferous deposits in Alberta, Canada, described under the name *Azonotetraporina? horologia* by Staplin (1960, Pl. I, fig. 4, 6) and believed to be alete spores are reminiscent of some examples of *Horologinella*.

Horologinella lineata sp. nov.

(Pl. XXXVII, fig. 1-3; holotype, fig. 1-2; P21459)

AGE AND OCCURRENCE: ?Albian-Aptian: Attadale Bore, near Perth, W.A. at 619 ft.

DESCRIPTION: Shell approximately isodiametric divided by a relatively deep median incision on both sides into an epitheca and hypotheca of nearly the same shape. The epitheca bears a small beak-like projection adjacent to which in the mid-line lies a small, concave, terminal opening. The surface of the shell is tabulated, the arrangement and shape of the fields being different on the two surfaces which for convenience are distinguished as ventral and dorsal respectively. The ventral surface is characterized by a long field which narrows gradually from near the epithecal opening to the 'waist line' the remaining fields being polygonal in outline and variable in shape. The dorsal surface is divided into approximately 6 relatively large 4-5 sided fields. The wall of the shell is relatively thick and finely granular.

DIMENSIONS: Holotype— 30μ long, 25μ broad. Paratype (fig. 3)— 24μ long, 25μ broad; another example 22μ long, 23μ broad.

Horologinella apiculata sp. nov.

(Pl. XXXVII, fig. 4; holotype P21461)

AGE AND OCCURRENCE: Campanian: Brickhouse Bore (1950) 10 miles SE. of Carnarvon, W.A. at 455 ft.

DESCRIPTION: Shell small, without fields, approximately isodiametric, sides deeply and broadly concave, epitheca and hypotheca of almost the same size and shape, epitheca with a small median beak-like projection by one side of which a small concave opening is situated. Wall relatively thick, surface smooth.

DIMENSIONS: Holotype— 21μ long, 20μ broad.

Horologinella incurvata sp. nov.

(Pl. XXXVII, fig. 5; holotype P21462)

AGE AND OCCURRENCE: Probably lower Eocene: Rottnest Bore, W.A. between 1285 and 1385 ft.

DESCRIPTION: Shell small, without fields and apical projection approximately isodiametric with deeply concave sides, no opening observed. Wall relatively thick, surface smooth.

DIMENSIONS: Holotype— 16μ long, *c.* 16μ broad. Range of four examples— $16-17\mu$ long, $15-18\mu$ broad.

COMMENTS: *H. incurvata* has already been recorded from the Rottnest Bore between 1285 and 1385 ft by Churchill (1960, p. 493, fig. 1 (3)) under the general designation 'fossil algal aplanospores'. The additional examples in our own preparations from between 1480 and 1541 ft in the same bore provide no further information regarding the nature and affinity of this form.

Horologinella? extrema sp. nov.

(Pl. XXXVII, fig. 10; P21467)

AGE AND OCCURRENCE: Cenomanian: Upper Gearle Siltstone, Rough Range South No. 1 Bore, core 68 (2717-2725 ft).

DESCRIPTION: Shell thin-walled with one diameter longer than the other, two of the four sides convex the other two so deeply concave that the two halves of the

shell are only attached to one another by a narrow 'neck'. No opening has been observed.

DIMENSIONS: Holotype—30 x 52 μ , width of 'neck' 17 μ . Paratype—30 x 55 μ .

Horologinella? obliqua sp. nov.

(Pl. XXXVII, fig. 9)

AGE AND OCCURRENCE: ?Upper Albian to Cenomanian: N. of Gingin, W.A. Wapet's Seismic shot hole B1 at 200 ft.

DESCRIPTION: Shell longer than broad, side walls slightly concave upper and lower walls running slant wise, opening relatively large placed to one side of the mid-line. Surface finely granular.

DIMENSIONS: Length of shell 62 μ , width of epitheca 54 μ , opening c. 20 μ .

Horologinella sp. indet

(Pl. XXXVII, fig. 15)

AGE AND OCCURRENCE: ?Aptian-Tlbian: Attadale Bore, W.A., at 619 ft.

DESCRIPTION: Shell squarish, approximately isodiametric, antapical wall slightly concave, opening median, surface granular.

DIMENSIONS: Figured specimen 40 x 40 μ .

Palaeostomocystis sinuosa Cookson and Eisenack 1960

Palaeostomocystis sinuosa Cookson and Eisenack 1960, p. 258, Pl. 38, fig. 16, 17.

COMMENTS: The small shells described from Upper Jurassic deposits at Broome, W.A. under the name of *P. sinuosa* are almost certainly of the same category as *Horologinella*.

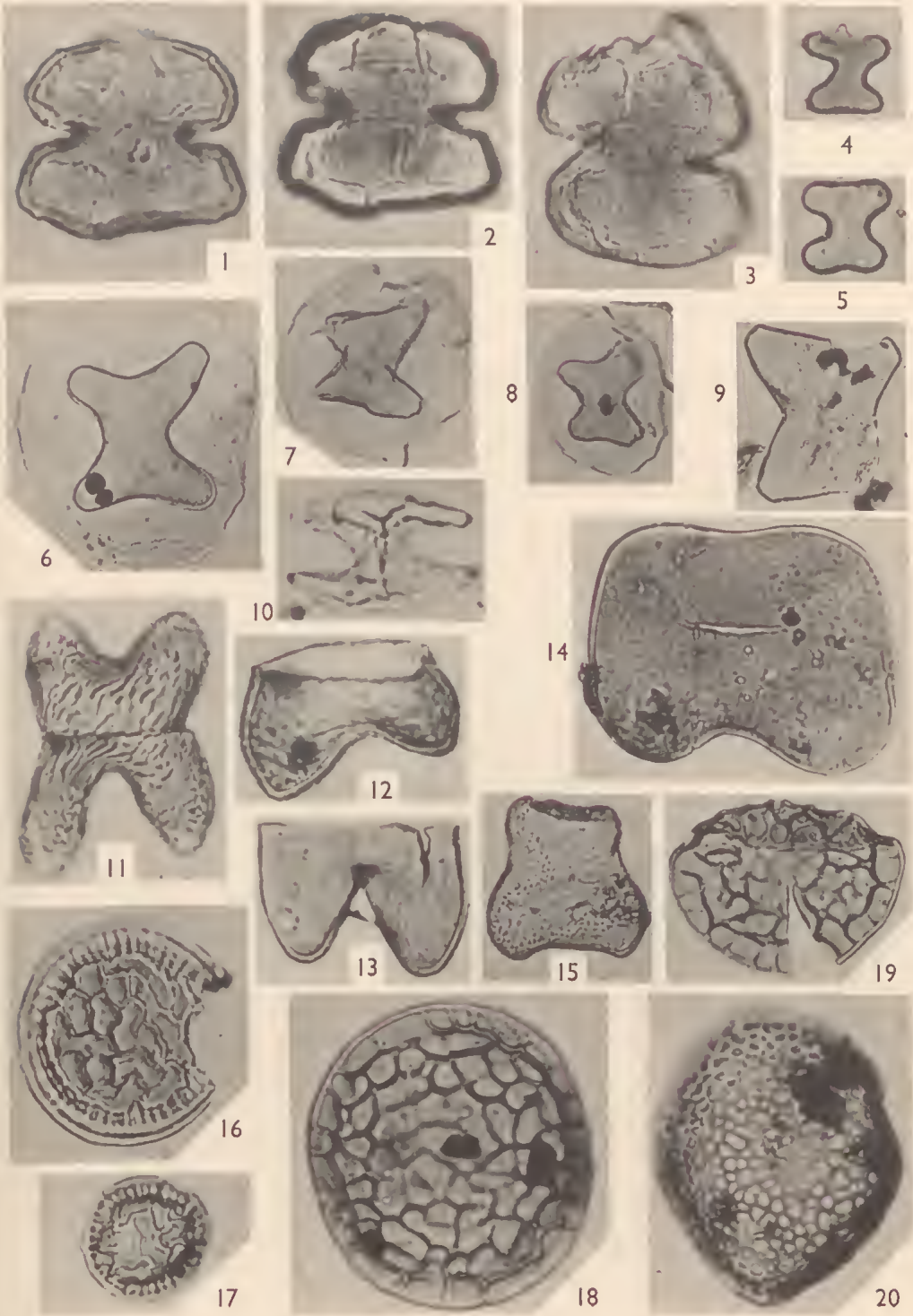
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Explanation of Plate

PLATE XXXVII

- Fig. 1-3—*Horologinella lineata* sp. nov. Attadale Bore, W.A. at 619 ft x c. 1300. 1, 2, ventral and dorsal surfaces of type; 3, dorsal surface of paratype.
- Fig. 4—*Horologinella apiculata* sp. nov. Brickhouse Bore at 455 ft x c. 650.
- Fig. 5—*Horologinella incurvata* sp. nov. Rottnest Bore, W.A. between 1480-1531 ft x c. 800.
- Fig. 6-8—*Halophoridia xena* sp. nov. 6, 8, Fremantle Traffic Bridge Bore No. 5 at 100 ft. 6, x c. 850; 8, x c. 57; 7, Power House Bore, W.A. at 478 ft.
- Fig. 9—*Horologinella? obliqua* sp. nov. Wapet's Seismic Shot Hole B1 at 200 ft x c. 400.
- Fig. 10—*Horologinella? extrema* sp. nov. Rough Range South Bore at 2717-2725 ft x c. 520.
- Fig. 11, 12—*Schizocystia rugoso* sp. nov. Fremantle Traffic Bridge Bore No. 5 at 100 ft x c. 530.
- Figs. 13, 14—*Schizocystia laevigata* sp. nov. Subiaco Bore at 358 ft (dark sample). 13, x c. 530; 14, x c. 520.
- Fig. 15—Affinity *Horologinella* sp. Attadale Bore, W.A. at 619 ft x c. 600.
- Fig. 16, 17—*Lecaniella margostriata* sp. nov. 16, Fremantle Traffic Bridge Bore No. 5, at 100 ft x c. 760; 17, Power House Bore, W.A. at 478 ft x c. 560.
- Fig. 18-20—*Lecaniella dictyota* sp. nov. 18, Power House Bore, W.A. at 640 ft x c. 540; 19, locality uncertain x c. 520; 20, Fremantle Traffic Bridge Bore No. 5 at 100 ft x c. 530.



THE VICTORIAN HIGH PLAINS SYMPOSIUM

14 September 1961

FOREWORD

One of the functions of the Royal Society of Victoria is to assist integration between the many sciences. In keeping with this aim, the Symposium sought to bring together available scientific information on the Victorian High Plains, and to provide an opportunity for discussion. To a large extent this was achieved. Also the lack of scientific data in many fields was made clear, thus providing an encouragement to further research.

For the purposes of the Symposium, the Victorian High Plains was defined as those areas of Victoria above the winter snowline, which is approximately the upper limit of the wet sclerophyll forest. It comprises the alpine and subalpine zones, which are above the montane zone. Geomorphologically, the high plains thus defined include both the high plateaux (which are part of an early Tertiary terrain), and the contiguous areas of dissected plateau country. The definition includes the Bogong High Plains, the Benison High Plains, the Howitt High Plains (also called the Snowy High Plains), the Dargo High Plains, the Mt Buffalo Plateau, and the Baw Baw Plateau.

NOTES ON THE GEOLOGY OF THE HIGH PLAINS OF VICTORIA

By J. L. NEILSON

General Geomorphology

Considerable portions of the areas known in Victoria as high plains are not plains at all in the usual sense of that word. They are rather areas of subdued relief, only limited parts of which have the flatness of true plains. For an area of low relief to be regarded as a high plain in Victoria, an elevation of at least 4,500 ft above sea level is usually required, and though arbitrary, this definition is used in these notes as a general guide.

The high plains are all situated within the Eastern Highlands. Occurring there amid a steep deeply dissected landscape, their appearance still strikes the traveller as remarkable. The topographic forms which they display vary considerably—from true plains, broad rolling landscapes crossed by old, mature and even youthful valleys, to broad ridge tops and gently rounded mountain summits. But they have this in common: they are physiographically late mature to senile, and they are always surrounded by terrains of much greater relief, deeper dissection. From these surrounding regions of deep dissection, the high plains are being attacked by rejuvenated streams of the present cycle of erosion.

The approximate extent of the high plains is shown on the accompanying map (Fig. 1). Portions of some of the high plains areas drop below 4,500 ft—particularly in the Wellington Tablelands and the Limestone Cr.-Cobberas area—yet they are still all classed as high plains as they are definite morphogenetic units. Because it is so extensive in New South Wales, the Monaro Plateau is included, even though in Victoria it scarcely reaches above 3,500 ft. Because of their elevation, the Wulgulmerang Plateau and the broad ridges connecting it with the Cobberas are not regarded as high plains, nor are the plains of Cobungra, Omeo and Benambra, even though these are all physiographically related to accepted high plains.

The problem of the physiographic evolution of the high plains awaits detailed geological and geomorphological studies before it can be fully elucidated. The high plains shown on the accompanying map are basically the residuals of a once extensive ancient land surface, eroded to a stage of low relief or partial peneplanation before being uplifted and extensively destroyed by rejuvenated streams. Preservation of remnants of this old surface has been assisted by the presence of resistant rocks such as granite, Middle and Upper Devonian lavas, and Upper Devonian sandstones.

The old erosion surface originated at no great height above sea level during the early Mesozoic, probably in the Triassic Period (Hills 1955), and may therefore be termed the Triassic surface. Later in the Mesozoic, it began to up-warp in the region which is now the Eastern Highlands, with concomitant down-warping further S. which formed sedimentary basins in central and south Gippsland. By the beginning of the Tertiary, some broad deep valleys had been cut in the up-warping surface. Flow remnants at such places as the Dargo High Plains and the Nunyong



FIG. 1

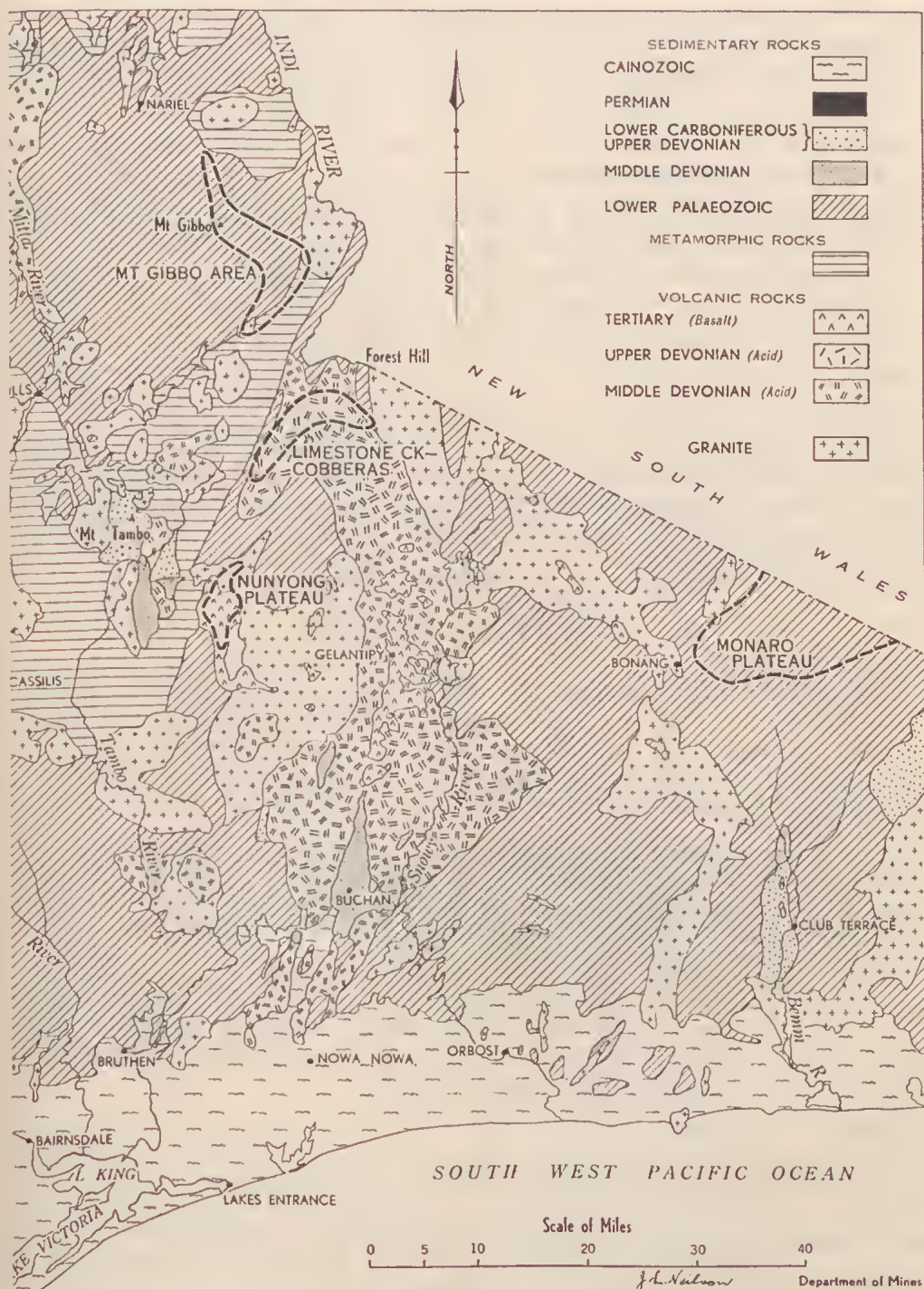


FIG. 1

Plateau indicate that basalt flowed down some of these valleys during Eocene-Oligocene times. However, not all the basalt flowed down valleys; some basalt cappings of the Bogong High Plains-Mt Hotham area rest on a fairly planar surface which must be the Triassic surface with little modification. The final phase of up-warping was the Kosciusko Uplift (Andrews 1910), which elevated the Eastern Highlands to their present altitude in the Upper Pliocene. With pulses of uplift occurring over such a prolonged period, streams have experienced phases of rejuvenation, which are attested by the valley in valley structures commonly found in the valleys of streams such as the Macallister R. and the Wonnangatta R. The rejuvenated streams, partly assisting active slope retreat, have reduced this once extensive land surface to the limited surviving areas now known as high plains.

It is possible that erosion surfaces of more than one age are represented in the high plains shown on the accompanying map. Baragwanath (1925) has recognized a younger erosion surface peripheral to the Baw Baw Plateau at about 3,500 ft, and while this can be traced to the head of the Yarra R., it has not been definitely recognized farther E., though it may be represented by the Monaro Plateau and the broad ridge tops of the Limestone Cr.-Cobberas area. The old Triassic surface, modified to some extent by erosion, is the main determining factor in the origin of most of the high plains. The extent of faulting in the Eastern Highlands is still largely unknown, though Beavis (1960, 1961) has demonstrated Cainozoic faulting in the Bogong area. Until more is known of Cainozoic faulting, certain correlation of separate high plain areas cannot be done in the absence of dateable deposits on their surfaces. Correlations made at present are largely provisional.

Geology of the High Plains

MONARO PLATEAU

The Monaro Plateau stretches into Victoria from New South Wales, where it is very extensive. It shows a broad rolling late mature topography; the streams crossing it generally have broad alluviated valleys, even near their heads, and carry water which flows northwards into the Snowy R. The plateau is bounded on the S. by very steep slopes and deep dissection, which contrast with the plateau topography.

The Monaro Plateau is cut in a terrain of steeply dipping argillaceous Lower Palaeozoic sediments, which at Delegate R. are intruded by granite. The drainage pattern, which is rectangular, appears to be influenced by strike ridges and possible cross faults. Soils on interflues are usually red-brown and clayey, while black peaty soils are common on the river flats.

Mt Delegate (4,307 ft) rises about 1,000 ft above the plateau as a monadnock, with distinctive radial drainage. It is probably the only relic of the Triassic erosion surface present. The average height of the Monaro Plateau in Victoria is about 3,000 ft. Its age, somewhere within the Tertiary, hinges on the age and relationships of the basalt remnants of Nimitybelle and Bombala.

LIMESTONE CR.-COBBERAS AREA

The broad ridge tops around the Cobberas area and the head of Limestone Cr. have a general summit level of about 4,500 ft, and are the surviving remains of an erosion surface which is now maturely dissected. Steadily decreasing in altitude, this surface can be traced eastwards towards the Wulgulnerang Plateau. The remains of this surface are preserved mainly on a landscape of resistant lavas of the Snowy River Volcanics (Middle Devonian).

The Cobberas (6,025 ft) rises above this surface as a monadnock—probably belonging to the Triassic surface—while the 4,500 ft ridge top surface belongs to a younger erosion surface which may be equivalent to Baragwanath's 3,500 ft peneplain near the Baw Baws.

MT GIBBO AREA

The high plains of the Mt Gibbo really consist of a broad divide whose average height is almost 5,000 ft. The divide has gentle rises and falls, with Davey's Plain as the only flat area of any size. The highest points are the broad summits of Mt Gibbo (5,479 ft) and Mt Pinibar (5,811 ft). To the E. and W. dissection is deep, with the steep valleys of the Indi R. and Gibbo Cr. almost 3,000 ft below.

The Mt Gibbo area is a remnant of an erosion surface cut mainly in steeply dipping Lower Palaeozoic sedimentary rocks, and appears to be a slightly modified relic of the Triassic surface.

NUNYONG PLATEAU

The flat topography of the Nunyong Plateau, approximately 4,500 ft above sea level, is due to the presence of an extensive residual of Older Basalt (Eocene-Oligocene). The basalt appears to have flowed in a southerly direction down one of the mature valleys cut in the up-warping Triassic surface by early Tertiary time. Substantial uplift since the extrusion of the basalt has led to very deep dissection by the Tambo R. and the Buchan R. on either side. The Nunyong Plateau has only survived because of the superior resistance to erosion of the basalt, while the adjacent ranges of softer rocks have been worn down.

The basalt seems contemporaneous with the basalts of the Gelantipy Tableland farther E., but all these basalts appear to be valley flows, it is doubtful whether one vast basalt plateau once linked the Gelantipy Plateau with the Nunyong Plateau, as Stirling (1887) suggests.

BOGONG HIGH PLAINS

The Bogong High Plains situated a little to the N. of the Great Divide, are both the highest and the largest high plains in Victoria. They form a composite landscape of low relief, composed of remnants of an erosion surface which was cut in gneisses and granites, and cappings of Older Basalt (Eocene-Oligocene) lying upon this. The flattest part of the Bogong High Plains is the large basalt residual centred on Mt Jim (5,916 ft) which, when viewed from across the Cobungra R. at Mt Loch appears flat. The high plains finish before Mt Nelse (6,267 ft) is reached, but fairly flat spurs stretch out towards Mt Bogong, until truncated by the deep youthful valley of the Big R. Similar ridges are found spreading out in other directions from the high plains, and really belong to the same land surface as the high plains.

The streams flowing across the high plains have broad shallow valleys and gentle gradients, with moss bogs common, but on reaching the edge of the plains, gradients steepen and streams enter deep youthful valleys. At the edge of the high plains, dissection is deep, and streams such as the Cobungra R., the Big R. and the heads of the Kiewa R. are rejuvenated and actively downcutting. Crohn (1950) mentions the importance of faulting in the rejuvenation of these streams; Beavis (1960, 1961) has further documented this faulting.

Across the Big R., in the environs of Mt Bogong (6,508 ft), is a limited area of low relief which seems to be part of the same land surface as the true Bogong High Plains, though rather higher.

The low relief landscape cut in metamorphics and granites is probably the Triassic land surface, slightly modified by erosion. The Older Basalt appears to be mainly sheet flows capping this old surface, but some of the basalt appears to occupy mature valleys cut in this surface by the early Tertiary.

HOTHAM TABLELANDS

The Hotham Tablelands are separated from the Bogong High Plains by the deep valleys of the Cobungra R. and the West Kiewa R. In the Mt Hotham area, they are represented by rounded ridge summits over 5,000 ft in elevation, with eminences such as Mt Hotham (6,101 ft) and Mt Loch (6,152 ft) rising slightly above the general level. Several miles E. of Mt Hotham, a change occurs, with broad rounded ridge summits changing to flat tableland topography on the Cobungra-Dargo divide. Here is the head of the Victoria R., and this flat tableland—of elevation 4,500-5,000 ft—is called the Paw Paw Plains by Stirling (1887). From the Paw Paw Plains, another tableland stretches eastwards along the Victoria-Cobungra divide, and eventually drops towards Cobungra.

The bedrock of the Hotham Tablelands is Ordovician slaty mudstone, which is fairly easily eroded when not protected by basalt cappings. Hence in the Mt Hotham area, where the only basalt is a small cap at Mt Loch, a general accordance of ridge levels is the only indication of an erosion surface. From Mt Higginbotham (5,870 ft) to the Paw Paw Plains and beyond, thin basalt cappings are common, and give the landscape a flat tableland appearance. The basalt residuals seem to be by plateau cappings rather than valley flows, though beneath the basalt of the Paw Paw Plains gravels indicate an old valley. The basalt has preserved remnants of the same erosion surface which is found on the Bogong High Plains.

DARGO HIGH PLAINS

On the divide between the deep valleys of the Upper Dargo R. and the Wonnungarra R., S. of Mt Hotham, is a broad area of basalt tableland known as the Dargo High Plains, which connects with the Great Divide at Mt St Bernard by a narrow ridge of Ordovician slate. The elevation of the plains is about 4,500 ft, with a slight slope to the S.

The basalt fills broad and deep valleys cut below the level of the Triassic erosion surface; gravels beneath the basalt indicate a deep lead heading from sub-basaltic gravels at the Paw Paw Plains on the Great Divide. The basalt, like the basalt remnants further N., belong to the Lower Tertiary Older Volcanics.

The valleys crossing the plains are broad but shallow, with peaty flats and moss bogs common. Only at the edges of the plains where basalt cliffs occur, has rejuvenation reached the area. A peculiar feature of some of the valleys on the plains is a step-like effect, which is due to both jointing and flow boundaries in the basalt.

WELLINGTON TABLELANDS

The Wellington Tablelands occupy the upper and middle parts of the basin of the Moroka R., and extend a little S. of it to the Wellington Plateau. To the N. they are bounded by the junction of Little R. with the Moroka R., while to the W. they finish at the Big Plain (c. 4,700 ft) above the upper Moroka R. The tablelands finish in the E. at the top of a high scarp, from which spurs rapidly drop about 4,000 ft to the Wonnangatta R. They are linked with the Bennison Plains, and Holmes Plain by a narrow ridge. The Wellington Tablelands show broad rather rounded divide tops, broad valleys which are not deep, but few areas which are reasonably flat, apart from the Wellington Plateau and the Big Plain. S. of the tablelands

surface in the Avon R. watershed, the steep valleys, sharp ridges and much deeper dissection make a strong contrast with the Wellington Tablelands.

The Wellington Tablelands lie within an area of resistant Upper Devonian sandstones and rhyolites, with moderately spaced folds and dips of 10-50°. At the E. edge, Ordovician slates and quartzites cut across the tablelands without causing change in relief.

Three main physiographic elements compose the Wellington Tablelands:

1. The broad ridge tops and summits at about 5,000 ft elevation, e.g. Wellington Plateau (Big Hill) (c. 5,000 ft), Mt Wellington trig. station (5,363 ft), Castle Hill (4,749 ft). They are slightly denuded relics of the Triassic erosion surface.
2. The Big Plain area (c. 4,800 ft). Adjacent to the upper Moroka R., this broad rolling area is an old broad strike valley (Thiele 1907), and represents the ancestral course of the Moroka R. The drainage now cuts across the strike to flow into the present Moroka. Its age is probably Lower Tertiary.
3. The Moroka Valley (c. 4,000-3,200 ft). From near the Mt Wellington trig. station, the upper Moroka Valley drops rapidly to the N. along a straight course, following the strike of the Upper Devonian rocks almost along the rhyolite-sandstone boundary. It is actively downcutting, and has captured the old strike drainage of the Big Plain.

Dissection of the Big Plain by the Moroka is beginning but as the Moroka R. is cutting down more rapidly than the small streams crossing the Big Plain, these small streams tend to join the Moroka from waterfalls or hanging valleys. These hanging valleys and the straight head of the Moroka suggest glacial action to Costin (1957) but they are readily explained as above.

The stream gradient soon lowers and the Moroka valley widens as it swings to the E. following the trends of plunging folds, to flow through a mature broad open valley, with river flats. Dissection is fairly shallow compared with the Avon Basin to the S. The Little R. flows westwards from Castle Hill to the Moroka through similar broad valley country with fairly shallow dissection. Both these broad valleys form a conspicuous saucer-like basin, which ends abruptly below the junction of the two streams, when the river begins to drop suddenly into a gorge.

BENNISON PLAINS, HOLMES PLAIN, SNOWY PLAINS, BRYCE'S PLAIN

From the flats of Shaw's Cr., close to Mt Tamboritha (5,381 ft) extending about 16 miles to the N. is an unbroken sequence of high plains. It is a mildly undulating landscape, with broad valleys, often with alluvial flats, and gently sloping valley sides. High points such as Mt Reynard (c. 5,600 ft) and Mt Arbuckle (5,525 ft) rise gently above the general level. The most southern part, the Bennison Plains, has an elevation of about 4,500 ft, rising to almost 5,000 ft at Holmes Plain and a little over 5,000 ft at the Snowy Plains before a drop of several hundred feet to Bryce's Plain.

The geology is remarkably uniform, with northerly striking Upper Devonian rocks dipping westerly at low angles. Rhyolites of the same age outcrop near the eastern edge of the plains.

This belt of high plains is a survival of the Triassic land surface, which is here only shallowly dissected on the high plains by the remnants of an ancient drainage system. The streams of the old system have a N.-S. trend, which is determined by the strike and the gentle W. dip of sandstone beds belonging to a worn down cuesta landscape (Davis 1899). The valleys are broad, with alluvial flats and moss bogs.

To the E. and W. of the high plains, dissection by the Carey R. and tributaries

of the Wonnangatta R. and the Caledonia R. is very deep. N. of Mt Arbuckle, a deep escarpment slope marks the eastern edge of the plains. During the present erosion cycle, vigorous heads of these streams have extensively captured the old strike drainage of the high plains. On the Snowy Plains, the old drainage system has been almost completely removed by capture, but further S., Shaw's Cr.—flowing close to the boundary between sandstone and rhyolite—survives.

HOWITT PLAINS

N. of Bryce's Plain, across a narrow neck, are found the remarkably flat Howitt Plains (c. 5,200 ft) from which heads the Caledonia R. They spread out northwards towards the broad summit of Mt Howitt (5,715 ft). The flat surface of the Howitt Plains is due to a capping of basalt, probably of Eocene-Oligocene age like the basalt of the Dargo Hill Plains. The basalt appears to lie on a fairly level surface.

COBBLER PLATEAU

The Cobbler Plateau (c. 5,300 ft) is composed of very gently dipping resistant pebbly sandstones of Upper Devonian age, and appears to be an exposed dip slope in these beds rather than an erosion surface remnant. It is surrounded on all sides but the S. with steep cliffs, which are steepest at the N. It connects with Mt Howitt to the S. via the serrated Crosscut Saw.

MT SKENE PLATEAU, MT USEFUL PLATEAU, CONNOR'S PLAIN

The flattened summit of Mt Skene (5,200 ft) composed of steeply dipping Silurian mudstones probably represents the slightly denuded Triassic surface.

Mt Useful (4,717 ft) and Connor's Plain (c. 4,500 ft) are both thin cappings of Older Basalt (Eocene-Oligocene) to which they owe their plateau-like summits.

MT BUFFALO PLATEAU, BAW BAW PLATEAU

Mt Buffalo stands as an isolated granite mass, with steep joint surfaces on most sides. The undulating summit which caps it has a general elevation of about 4,500 ft, while the highest point is The Horn (5,645 ft). Joints appear to determine the main drainage lines on the plateau.

The Baw Baw Plateau is remarkably similar to the Buffalo Plateau. It is cut in granite, its average level is about 4,500 ft, with Mt St Phillack (5,140 ft) as the highest point. The Baw Baw Plateau is undulating, and again, the stream pattern is determined by jointing (Baragwanath 1925). Both plateaux appear to be slightly dissected residuals from the Triassic land surface.

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THE DISCOVERY OF THE BOGONG HIGH PLAINS

By STELLA G. M. CARR

The Bogong High Plains were discovered by two stockmen, James Brown and John Wells, who were employed to look after the run at Cobungra which was taken up by George Gray in 1851. Gray, accompanied by Brown, Wells and two others, brought his cattle to Cobungra from a property called The Pelican, near Wangaratta. The move was undertaken immediately after the bushfires of Black Thursday (13 February 1851), when it became necessary to find grass for the cattle which survived. The route taken by Gray and party was as follows. They went first to Lockhart's Gap but finding no grass there they went on to Mitta Mitta Station, then held by Bowler. Again there was no grass available, but they fell in with an aboriginal called Larnie, who told them of Cobungra and offered to take them there. From Mitta Mitta they climbed the Gibbo Ra., went down the other side to Hinnomunjie Station (taken up in 1842), then on up Livingstone Cr. to the Bingo Gap. From the valley of Bingomunjie Cr. they crossed into the valley of the Cobungra and established their first camp at Dick's Cr. (now Crown Allotment 28, Parish of Bingomunjie). In the course of the next few years they moved further upstream and settled on the Victoria R. (Crown Allotment 11, Parish of Bingomunjie). The licence for the run is dated 4 June 1851. Its boundaries are not defined but it can be assumed that a boundary was agreed upon between it and the territory held by Hinnomunjie Station. Although Gray is officially the first to have held Cobungra he believed that others had been there before him. Andrews (1920) records that Cobungra was held by the Wells Brothers in 1842, but the source of this information has not yet been traced. There is no local tradition to support the statement. It appears clear, however, that Gray and his party were the first to open up the track between Mitta Mitta and Hinnomunjie. In the next few years it was much used by miners, by the Grays themselves, and by others who took cattle to market at Beechworth. The route also provided a very useful link between the North-east and the track between the Monaro and Gippsland which had been established some years earlier.

After their arrival in March 1851, Brown and Wells were left at Cobungra in charge of the cattle and lived there for some years. Brown realized that the track over the Gibbo Ra. was circuitous and argued that there must be a shorter way to Beechworth. Larnie had described to them as well as he could the Bogong High Plains and had told them also that the Omco and associated tribes of aboriginals went to the High Plains from their camp at the Bundarra R. via Bucketty Plain, that is, along the spur which joins the High Plains at Mt Cope. Brown and Wells followed this track and, once on the High Plains, set off in the direction of Mt Nelse. From the Nelse end of the Plains they had a view of the great spur of The Fainter and decided that it was the one to follow. By doing so they found their way into the North-east. It is not known whether it was on the return from their first trip or on their second journey that they found the alternative route over Mt Hotham, but they established both routes before they had been at Cobungra

for three years, and had also been over Mt Feathertop. Very shortly after the discovery of gold in Omeo (April 1854) the track over Mt Hotham was much used by miners and until recently there were in Omeo people still living who had been brought to the district as children over this track early in 1855.

Some of the names given by Brown and Wells to parts of the country still remain in use. Rocky Valley, Pretty Valley, Rocky Knobs, Mt Jim, Jim Stream, Feathertop, The Fainter, The Niggerheads, The Razorback, Blowhard and Bucketty Plain are well known. Skiers at Mt Hotham know J. B. (Plain), where Jim Brown carved his initials on a tree, the Old Wangaratta Bridge and Australia Drift. Other names were not officially recognized but are still in local use. Brown called Mt Hotham 'Baldy', and Mt Cope 'Mt Jack'. The older cattlemen still regret that Mt Jack is not the official name. Jim Brown and Johnny Wells are remembered as very great bushmen. Of the two, it is said that Jim Brown was the finer.

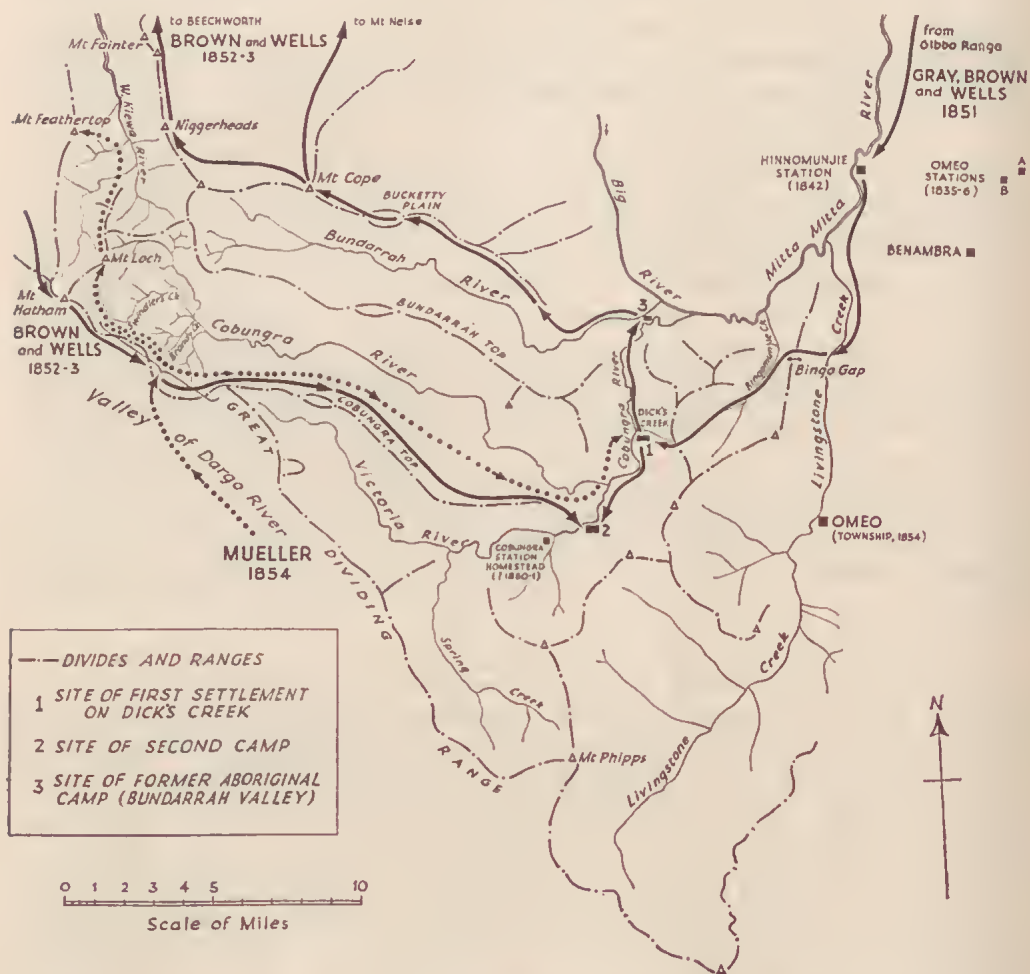


FIG. 1.

As it is generally believed that Baron von Mueller discovered the High Plains his claim to this distinction will now be considered. The relevant portion of his report is given in Appendix I.

He visited the North-east of the State in 1854, crossing the Dividing Ra. from the valley of the Dargo R. 'near the upper part of the Cobungra'. At the time he thought he had discovered the highest mountains in Australia and claimed to be the first civilized man to visit the area. Mueller climbed two peaks, one of which he wished to name Mt Latrobe, on 3 December, and the other which was to be called Mt Hotham, on 6 December. The identity of these peaks remained a mystery for many years because the compass bearings on other, already known mountains which he took from Mt Latrobe could not be reconciled with the more accurate work of later surveyors. However, Wakefield (1949) following a suggestion made by Barnard (1904) showed that if Mueller's compass readings are corrected to $33\frac{1}{2}^{\circ}$ Mt Latrobe can be identified as Mt Loch and Mt Hotham as Mt Feathertop. The compass error is attributed to magnetic interference from the Older Basalt capping of Mt Loch. This explanation is a very reasonable one, but Wakefield's interpretation of the route by which Mueller reached these peaks is open to some doubt.

Wakefield, relying on an old, very inaccurate sketch plan (not Mueller's) dated 1864, and perhaps misled by the mention of the Mitta Mitta (actually the West Kiewa R.) assumed that Mueller crossed the Divide near the site of the present-day Cobungra settlement, travelled by way of the Bundarra Top to the High Plains and thence to Mt Loch. It is difficult to justify this explanation either on the basis of the extent to which the geography of the area was known in 1854 or from Mueller's very brief report. After mining began, there was a great deal of traffic between Cobungra and the Dargo but there is no record or hint of any link between the two districts in 1854. Mueller does not mention his sources of local information but it can be argued that he had access to more than he acknowledged. For instance, he knew the name of the Cobungra and that the Cobungra and Dargo R. have a divide in common. He also knew that the Cobungra waters reached the Murray—a point which would not be obvious at the first sight of the headwaters and, further, he was able to make his way from Mt Feathertop to Omeo. In the absence of local knowledge this would have been a complex and difficult journey, chiefly because of the curious stream pattern of the intervening country.

Mueller's report states that, on leaving the Dargo valley (a) he traversed a grassy tableland in a NE. direction 'along the Cobungra downwards', (b) until the country to the N. appeared practicable and that (c) the ranges were timbered with *Eucalyptus pauciflora*. It is not clear whether Mueller distinguished between the Cobungra and its major tributary, the Victoria, into which Spring Cr. flows. If he did not do so he could have crossed the Divide anywhere between Mt Hotham and Mt Phipps. As the Divide and the major valleys all run approximately NW.-SE. in this area, the further he was from Mt Hotham when he made the crossing the more impossible it is that a course to the NE. would have allowed him a view of Mt Loch to the N. This strongly suggests that he crossed the Divide as he said, near the upper part of the Cobungra itself.

A closer examination of Mueller's statement in relation to the geography of the area confirms this. In the Divide between Mt Hotham and Mt Phipps three parts can be distinguished: the Spring Cr. section, the Victorian R. section and the Cobungra section. Table 1 sets out the extent to which each of these sections satisfies Mueller's description of the journey.

TABLE 1

Section of main Divide	Grassy tablelands	Stream course	View of mountains to the N.	Forest type
Spring Cr.	Not extensive	NE.	No	Higher parts <i>E. pauciflora</i> mostly mixed species
Victoria R.	In higher parts only	SW.	No	Higher parts <i>E. pauciflora</i> otherwise mixed species
Cobungra R.	Extensive	Large tributaries (Brandy Cr. & Swindler's Cr.) NE. Main stream E. of S.	Yes	<i>E. pauciflora</i>

It will be seen that the upper part of the Cobungra fulfils all the conditions. It seems most likely, therefore, that Mueller crossed into this area because the top and the spurs on the Cobungra side form, in places, a broad tableland and some of the spurs and tributaries (Brandy Cr. and Swindler's Cr.) run N.-E. It seems reasonable that Mueller rode across the top until he could get a clear outlook and then made for Mt Loch. Once there, Machinery Spur would present itself as an obvious route to the foot of Mt Feathertop.

This explanation is also satisfactory in that if, as it has been supposed, there was no link between the settlements in the Dargo valley and Cobungra at the time, once in the Dargo valley, Mueller would have had no reason (except the roughness and difficulty of the country) to leave it until he reached the headwaters. In conclusion, it is necessary to say that although there is no tradition that Brown and Wells saw Mueller on his way through, it seems likely that he made his way to Omeo by following the Cobungra downstream until he found their track leading to Omeo. On his journey from Omeo to Mt Kosciusko and his return to Gippsland via the Buchan R., Mueller undoubtedly followed the tracks established when settlement was extended from the Monaro to Benambra and the N. part of East Gippsland. To record these things does not detract from Mueller's achievement. His was a great and difficult journey, but it is more correct to regard him as the first official visitor than to accord him the status of original explorer.

Acknowledgements

The data were gathered while the author was on the staff of the Victorian Soil Conservation Authority and later of the University of Melbourne. Thanks are due to Dr S. L. Duigan, who assisted with the preparation of the manuscript, and to Miss J. Wood who drew the map.

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Appendix I

Extract from Mueller's Report (1855)

Left Avon on the 22nd November, thence up the Mitchell, Wentworth and Dargo Rivers, and crossed the Dividing Range between the waters of Gippsland and the Murray near the upper part of the Cobungra. Thence I traversed the grassy tableland in a north-easterly direction, along the Cobungra downwards, until the country appeared practicable towards the north, to reach the highest part of the Bogong Ranges. The ranges hereabouts have never been traversed by civilised men. They are timbered with Mountain Gum-tree, *Eucalyptus phlebophylla*.* On the 3rd December I ascended the south-east of the two highest mountains of the Bogong Range, and believed it to be nearly 7,000 feet high. The much more abrupt and yet higher summit of the north-west mount I ascended from the Upper Mitta, which skirts the base, on 6th December; unquestionably several hundred feet higher. On both mountains mighty masses of snow lay far below the summit. Considering that mountains of such altitude, probably the two highest on the Australian continent, deserve distinctive names, I solicit His Excellency's permission to name the grandest of both Mt. Hotham, and the second in height Mt. Latrobe, as I trust to be entitled to the great honour of being the first man who ever reached these commanding summits of the Australian Alps.

* Now *E. pauciflora* Sieb.

Appendix II

A full account of the Gray's journey to Cobungra is in the possession of the author. It was given by Mr Michael MacNamara and his brothers, the late Edward and the late Patrick MacNamara, grand-nephews of George Gray. It was confirmed by the late Mr George Fitzgerald and the late Mr John MacCrae, both of whom also provided information about the discovery of gold in Omeo. All these people knew Brown and Wells. The dates in the original account and the information given concerning the names of the owners and managers and the boundaries of the various stations in the early part of 1851 have been checked by reference to other sources, some of which are official documents. These provide other corroboration of the verbal evidence. The original licence issued to George Gray was seen at the Department of Lands and Survey, Melbourne.

THE SOILS OF THE HIGH PLAINS

By A. B. COSTIN

Abstract

The soils of the high plains are mainly alpine humus soils, with lithosols, bog peats and humified peats. There are also smaller occurrences of acid fen peats, acid marsh soils, gley podzols, and snowpatch meadow soils.

The properties of the alpine humus soils, lithosols and bog peats are discussed with special reference to plant-water relations, soil erosion and water yield.

Certain soil properties, and some of the soils themselves, have been developed under conditions which are not active today. It is suggested that recent periglaciation has been an important factor.

Introduction

In comparison with the agricultural and pastoral soils of the State, the soils of the high plains have received little study and are still incompletely understood. Early work described them as being either peaty or shallow and rocky (Prescott 1931), and this impression remained for many years. However, subsequent studies in the Snowy Mountains area revealed a more complex pattern (Costin 1954), which has since been found to exist on the Victorian high plains as well (Costin 1957b). In addition to the peaty and rocky types, there is a variety of organo-mineral soils which are often extensively and deeply developed.

Classification and Distribution of the Soils

Table 1 provides a classification (after Hallsworth and Costin 1950) of the main soil groups recognized on the high plains, together with summarized environmental data.

Of the 8 groups listed, the acid fen peats, acid marsh soils (syn. silty bog soils), snow patch meadow soils, and gley podzols are relatively uncommon, with a combined extent of probably less than 5% of the total area; they will not be considered further here. Attention will be concentrated on the alpine humus soils, lithosols, and bog peats (with associated humified peats) which together cover the remaining 95% or more of the high plains. The relative proportions of these 3 groups, in the order listed, are probably of the order of 20:1:1, with local variations depending on whether the area concerned is a plateau and hence suitable for the accumulation of bog peat, or steep and dissected and more favourable for lithosol development (cf. Costin 1961: Fig. 2). The main plateau areas are the Bogong High Plains, Buffalo Plateau, the Dargo High Plains, Howitt Plains, the Snowy Plains, the Benmison-Mt Wellington area, and the Baw Baw Plateau. The steeper mountains include the Loch-Hotham-Feathertop area, the arc of mountains from Mt Cobbler to the Bluff, and individual peaks such as Bogong, Buller, Stirling, Gibbo, Pinnibar and the Cobberas (cf. Costin 1957a).

Alpine Humus Soils

The alpine humus soils, the most widespread group, are the climatic climax formation of the high plains. This is evident from their occurrence on all types of

TABLE 1
Soil Groups of the High Plains, and Environmental Data

Soil Group	Distribution and Environment
Organo-mineral soils in which the profile shows no eluviation of sesquioxides; acid to strongly acid throughout:	
Alpine humus soils	Widespread on all rock types and under most physiographic conditions. Vegetation subalpine woodland, sod tussock grassland, heath and tall alpine herbfield.
Mineral soils showing no profile differentiation:	
Lithosols	Locally widespread as current soils in exposed situations and as fossil soils under more sheltered conditions; all rock types, but especially strongly jointed or fractured rocks such as columnar basalt. Vegetation mainly heath; sometimes lacking as on large screes.
Organic soils with high water table, usually near surface level:	
Bog peats	Locally widespread in permanently wet, acid situations, due to springs and seepages on slopes and a high water table along valleys. Bog vegetation.
Acid fen peats	Minor occurrences in permanently wet, level to gently sloping situations, acid but with a small base supply. Fen vegetation, occasionally short alpine herbfield (snowpatch communities).
Humified peats	Locally common in association with drained bog peats.
Organo-mineral or mineral soils with a high water table:	
Acid marsh soils	Minor occurrences, usually associated with acid fen peats, in swampy situations receiving washed-in soil and mineral matter. Fen vegetation, occasionally sod tussock grassland.
Snow patch meadow soils	Restricted to wet, lower snowpatch situations, which continually receive suspended soil and rock material during the snow-melt period. Short alpine herbfield vegetation.
Gley podzols	Locally common in damp situations with an acid water table in the subsoil for most of the year. Vegetation mainly sod tussock grassland, and heath transitional to bog.

topography other than waterlogged and precipitous sites; on parent materials as diverse as granite (e.g. Bogong High Plains), basalt (e.g. Bogong High Plains and Dargo), and sandstone (e.g. the Bluff); and in association with several distinct vegetation types.

PROFILE MORPHOLOGY

The soil profile is of the A-C type, in which the organo-mineral topsoil of good crumb structure, porosity and friability grades through increasingly mineral soil into the more compact parent material beneath, without the development of illuvial horizons of humus, sesquioxides or clay. Textures vary from sands to clay loams, depending on parent material, and become stonier with depth. Floaters usually occur throughout, and in the deeper horizons distinct stone lines and stone layers are often developed. The depth of the profile varies from less than a foot to several feet, but the essential morphological features remain the same. Attention has already been drawn to the generally greater depth of these soils in comparison with soils of many similar mountains overseas, and to the lack of podzolization

despite the cool, moist conditions which prevail (Costin 1955). These differences have been related to the milder glacial history of the Australian high plains, their gentler slopes and more favourable soil climate, and to the circulation of soil material by the vigorous growth and decomposition of herbaceous species and by earthworm activity. However, the significance of these relationships has not yet been critically examined.

ANALYTICAL DATA

The soils are acid to strongly acid throughout, with pH values of 4.5 in the surface increasing by about half a unit in the subsoil. Typical organic matter contents are 10% in the topsoil decreasing to about 2% in the lowest horizons. In the alpine humus soils developed on gneissic granite in the Kosciusko area (Costin, Hallsworth and Woof 1952), cation exchange capacities are determined mainly by the organic matter: consequently they have moderate values in the topsoil (e.g. 15 m.e./100 g.) but very low values at greater depths (e.g. 5 m.e./100 g.). The exchange capacity is highly base-unsaturated, as would be expected from the high acidities. However, silica-sesquioxide and free ferric oxide determinations show no evidence of podzolization. The clays are largely clay biotite, with kaolinite and some free ferric oxide and hydrated aluminium oxide; this composition indicates a relatively slight degree of chemical weathering, a consequence of the cold environment.

WATER RELATIONS

Soil properties of importance in plant-water relations include those affecting the ability of the soil to absorb, retain, detain and transmit moisture.

In the Kosciusko area, on granitic soils similar to those in granitic areas of the Victorian high plains, infiltration capacities are greater under moist than dry conditions (Costin, Wimbush and Kerr 1960); this is the reverse of normal experience with less organic soils (Marshall 1959). The most critical conditions as regards surface run-off and soil erosion are therefore thunderstorms during the summer months. On well vegetated soils, infiltration rates after dry spells are of the order of 1"/30 minutes, compared with less than 3/4" on poorly covered soils; the relationships between infiltration and amount of herbaceous cover on a group of otherwise similar plots at Kosciusko is shown in Fig. 1. On the Bogong High Plains Carr and Turner (1958a) have also measured higher infiltration rates on soils with denser vegetation.

Approximate values for bulk density, and available water as determined by the difference in water content between tensions of 100 cm and 15 atmospheres are shown in Table 2. These results are for well developed granitic soils at Kosciusko; in shallower stonier soils the available water is rather less.

It will be noted that on a weight basis the organo-mineral horizons contain more available water than the subsoil. On a volume basis, however, which is the more

TABLE 2
Bulk Density and Available Water of Alpine Humus Soils

Depth (ft)	Bulk Density (gm/cm ³)	Available water	
		gm water/gm soil	In. of water/ft
0-1	0.85	0.27	2.8
1-2	1.30	0.27	4.2
2-3	1.50	0.26	4.7
3-4	1.52	0.21	3.8

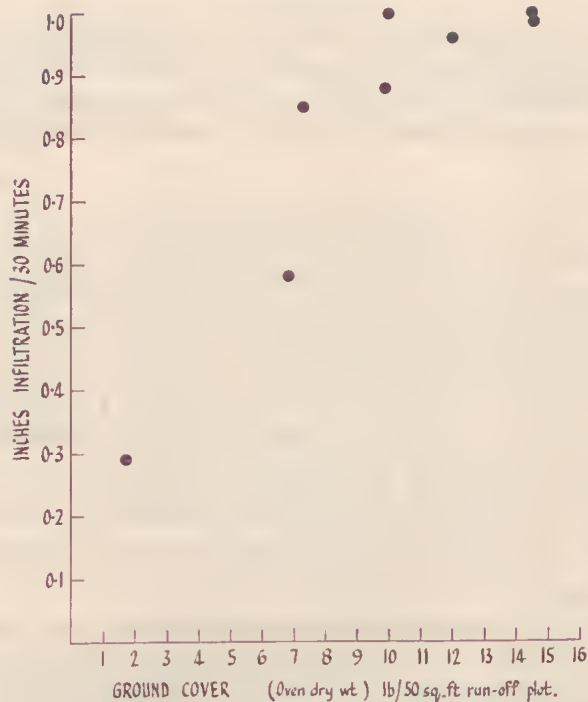


FIG. 1—Relationship between infiltration and amount of cover.

real expression, the surface soil contains least available water. Table 2 can be used to obtain an approximate measure of the water available for any plant or plant community of which the effective root depth is known. For example, minor herbs with most of their root system in the surface foot would have access to about 2.8" of water, perennial grasses and shrubs with effective root systems down to 2 ft about 7", and deeper rooting trees at least 10". Calculations made from soil data of Carr and Turner (1958b) for the Bogong High Plains indicate close agreement with the Kosciusko values; at Bogong the available water in the surface 3" is about 0.6" compared with about 0.5" for Kosciusko.

It is instructive to compare the amounts of available water in Table 2 with evapotranspiration during the snow-free months, calculated on the assumption that maximum values would probably not exceed 75% of the measured evaporation from a free water surface (cf. Penman 1948). Using S.E.C. meteorological data for the Bogong High Plains (Carr and Turner 1958a) estimates have been made of average potential evapotranspiration from October to May, and compared with average precipitation for the same period (Table 3).

It will be seen that under average conditions the calculated potential evapotranspiration exceeds precipitation only in January when the atmospheric deficit is 1.6". Plants are thus unlikely to experience severe water stresses outside this period. Whether such stresses develop will depend largely on the root system of the plant concerned. Reference to Table 2 indicates that most plants with effective root systems a foot or more in depth should have access to sufficient soil moisture during the dry period to maintain evapotranspiration near the potential rate. The available

TABLE 3
Precipitation and Potential Evapotranspiration—Bogong High Plains

Moisture Conditions	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precipitation	10.07	7.26	5.52	3.92	5.30	5.02	7.97	8.42
Potential Evapotranspiration	2.72	4.25	5.09	5.48	4.28	3.41	1.55	0.66
Difference	7.4	3.0	0.4	—1.6	1.0	1.6	6.4	7.8

water stored within the surface 7" is about the same as the atmospheric deficit of 1.6", so that the plants with shallower root systems will undergo temporary and sometimes permanent wilting. Plants with root systems between 6" and 12" may occasionally wilt, but only temporarily. However, the rainfall shows considerable variability (Carr and Turner 1958a), so that in drier than average seasons longer periods of water stress can be expected. These predictions are in general agreement with the field observations made by Carr and Turner (1958a).

In somewhat drier environments such as the Bennison-Howitt-Bluff area, potential evapotranspiration may exceed precipitation for at least 2 months. These higher atmospheric deficits, combined with the lower water holding capacity of the soils of this area (mainly Devonian sandstones and shales) are likely to result in depletion of soil water down to 1-2 ft.

The above estimates, which in the Kosciusko area have been confirmed by soil moisture measurements, have important implications for water yield, as well as for plant growth. With the possible exception of the drier high plains areas and stony or sandy soils of very low water holding capacity, water use by different native plant communities should be about the same, since most of the dominant species, whether herbs, shrubs or trees, have root systems which extend down to 2 ft or more. Consequently replacement of one vegetation climax by another is unlikely to materially affect evapotranspiration and water yield. More drastic vegetation changes, such as replacing the dominants by shallow rooting herbs like sorrel or white clover, or destruction of the vegetation altogether, could reduce evapotranspiration by about 2-3" a year; however, surface run-off and soil loss would be increased (p. 293) and the deposition of snow, rain, cloud and fog would be reduced (Costin 1961).

The permeability of soils to water is important both for plant growth and for water yield. In the case of plant growth, water movement in the unsaturated condition is usually more significant; for water yield, it is movement under saturated conditions. Total porosities of granitic soils in the Kosciusko area vary from about 40-50% of which more than half consist of non-capillary pores. Consequently saturated permeability is likely to be high, and unsaturated permeability relatively low (Marshall 1959). The first prediction is borne out by the observation that during the snow-melt period most of the melt-water percolates rapidly through the soil without the development of perched water tables; at Kosciusko the soil water content in a 6 ft profile decreases from about 35% to 10% in less than two days. The second prediction is supported by the temporary wilting of herbs such as *Craspedia uniflora* Forst. f. during sunny weather although the soil is often moist in the root zone as a whole; presumably the rate of soil water movement under unsaturated conditions is too low to satisfy the local moisture stresses developed at the soil-root interface, until after transpiration ceases at nightfall.

Noteworthy features of soil temperatures are the general lack of freezing, except superficially under certain conditions, and the chilling effects of large volumes of snow-melt water in spring. Although mean air temperatures are below freezing for 1-4 months, the soils as a whole do not freeze because during this period the ground, still relatively warm from summer, is effectively insulated by snow. During the snow-free months, however, when radiation frosts frequently follow warm days, exposed surface soils freeze with the development of needle ice. The source and movement of moisture required for the formation of the ice needles are still obscure. A large part of the moisture seems to be derived from the soil itself, and to move in the vapour stage in response to steep gradients in temperature and vapour pressure between the soil a few inches deep and the air-soil interface. The action of the needle ice is to lift up and loosen the surface soil, and to facilitate its drying out next day, thus leaving it susceptible to wind and water erosion. Another consequence of frost heave is the death of seedlings. By contrast, well vegetated surface soils are insulated against all but the most severe frosts, and effectively resist frost heave.

On the high plains the well-known lag between soil and air temperatures is suddenly evened out during the snow-melt period, when large volumes of water percolate through the soil. During this period soil temperatures are reduced to near freezing point down to depths of several feet. Although this is the period when the soil contains most moisture, trees and shrubs which project above the snow are more likely to undergo wilting than at other times of the year. If strong winds and sunny days accompany the snow-melt period, individual branches of snow gum and occasionally whole trees will wilt and within a few days the leaves begin to turn brown. The critical factor is probably the large increase in the viscosity of water which occurs as it approaches freezing, and the consequent restriction of water movement from soil to root and root to trunk (cf. Handley 1939).

EROSION

It will be apparent from the soil properties described that influences such as fires and grazing which substantially reduce soil cover will increase surface run-off and frost heave and consequently lead to greater erosion by water and wind. Slight to moderate surface erosion of alpine humus soils is now widespread on the high plains, and in some of the highest areas the whole soil mantle is being removed down to an erosion pavement of stones (cf. Costin 1957b). In these areas the inability of the vegetation to prevent complete stripping of the soil, once active erosion has commenced, suggests that the climate has recently become more severe, as postulated in New Zealand (Tussock Grassland Research Committee 1954).

Lithosols

Many steep mountain tops in Victoria, both on the high plains and elsewhere, have extensive rock outcrops on which the formation and accumulation of soil material is minimal. Under these conditions plant roots are largely confined to joint planes and cracks. Such soils are termed skeletal, or lithosols.

Rocky soils of another type also occur on the high plains, sometimes on gentle slopes and in situations which are now relatively protected. These lithosols are generally rather deep and largely consist of angular fragments ranging in size from large boulders to stones a few inches across. The stones in a particular situation are often of more or less similar size, and considerable amounts of finer soil material may occur between them. Drainage is mostly free, in which case the vegetation is heath or only lichens. When the lithosols occur just below springs and seepages, the heath communities usually grade into bog upslope.

These lithosols occur in many forms and sizes, from the huge scree of the Cobungra Valley below Mt Loch and the Valley of the Macalister in the Howitt area, to the widespread moraine-like accumulations of boulders in valleys and along minor streams. Occasionally distinct patterns are developed, in which the individual stones may be sorted into fractions of similar size. The most striking patterns are stone rings or polygons, up to several feet across, seen on gentle slopes of the Bogong High Plains near Mt Jim, on the Dargo High Plains and elsewhere. As the slopes increase the polygons become elongated into more or less parallel stone stripes. Rock rivers or block streams are a similar, but larger development; there are striking examples on the Dargo High Plains (cf. Carr and Costin 1955, Costin 1957c).

Most of the smaller occurrences of lithosols have been largely covered by vegetation, and the larger ones are being colonized from the edges and isolated centres. There is little evidence of active lithosol formation under present conditions, although there is still slight movement on some of the steeper slopes. Few vascular plants can grow successfully under these conditions. On the high plains the prostrate conifer *Podocarpus alpinus* R. Br. is almost unique in this respect. It may be significant that the roots of this pioneer species are nodulated; however, the effectiveness of the nodule organisms has not yet been examined.

The lithosols have very high permeabilities. Those which occur below springs and seepages, and across streams and drainage lines may be effective, therefore, in recharging groundwater and regulating stream flow; if so, they might be used for large-scale water spreading. These possibilities are being examined in the Kosciusko area.

Bog Peats

The bog peats are locally widespread in permanently wet, acid situations. On steeper slopes, where the wetness is localized to springs and seepages, the peat rarely covers more than an acre and often no more than a square chain. Along gentler sloping valley bottoms and on broad cols the peat may be many acres in extent. Depths of up to 10 ft have been recorded (Carr and Turner 1958a) but mostly they are less than 5 ft.

By definition, bog peats contain at least 20% organic matter, part of which is made up of bog mosses, and they are strongly acid in reaction. On the high plains, the average organic matter content down the profile is about 70%, on the basis of Walkley-Black determinations, and pH values are between 4 and 5. The main peat-forming plant is the bog moss, *Sphagnum cristatum* Hpe. with sedges (mainly *Carex guadichaudiana* Kunth.) and several epacridaceous and myrtaceous shrubs.

The profile is rarely uniform from top to bottom. The surface peat is often spongy, yellowish brown in colour, and largely undecomposed. It becomes darker, more compact and decomposed with depth. There is often an irregular alternation of different peat types, and sometimes a rather sudden change in the properties of the peat at some intermediate depth. Most of these features are described below for the profile exposed by the tributary of Middle Cr., above the Rover Hut on the Bogong High Plains:

- 0-16"—Yellowish brown fairly spongy and porous, largely undecomposed *Sphagnum* peat
- 16-32"—Yellowish brown, more compact and decomposed *Sphagnum* peat, fairly sharply separated from
- 32-34"—Brownish, more compact and decomposed *Sphagnum*-sedge peat
- 34-37"—Yellowish brown, slightly decomposed *Sphagnum* peat
- 37-39"—Brownish, well decomposed *Sphagnum*-sedge peat
- 39-42"—Yellowish brown, partly decomposed *Sphagnum* peat

- 42-44"—Brownish black, partly decomposed *Sphagnum*-sedge peat
44-46"—Brownish, partly decomposed *Sphagnum* peat, sharply separated from
46-51"—Brownish black, greasy, well decomposed sedge peat, resting on
51-60+—"—Brownish black gravelly mineral matter.

The above profile is interpreted as showing evidence of a fairly uniform and rapid period of *Sphagnum* development down to 32", an intermittent and probably longer period of *Sphagnum* development between 32 and 46", and an early period of fen development below 46". The 32-46" stratigraphy can be interpreted in terms of the well-known hollow-hummock pattern of bog development (Tansley 1949), not necessarily autogenic (cf. Walker and Walker 1961), but reflecting variations in external bog conditions of water- or base-supply. The basal layer of fen peat is a usual feature which shows that most of the bogs have developed from an early fen stage. The coarse textured substrate is also common, and frequently consists of large angular stones.

At the present time there seems to be little active peat formation on the high plains. The bog surface consists mainly of shrubs typical of the stillstand and degeneration stages (cf. Tansley 1949, Costin 1954), with few active *Sphagnum* hummocks. The main influences responsible for these conditions are fires and trampling of the bog surface, and drainage due to the entrenchment of gullies and creeks (Costin 1957b). Much of the drying out has occurred within the last 40 years (Carr and Turner 1958a).

Problems of Soil History

As far as possible the properties of soils themselves should provide the evidence for their history and development.

Important features of the alpine humus soils in this regard are their often considerable depth, and their development not only on bedrock but within soil and rock material which shows evidence of earlier mixing and downslope movement. Floaters occur at most levels and often tend to be orientated in the direction of slope; so do the stones of the basal stony layer where this is present. Occasionally lenses of more organic soil occur at depth in what is otherwise largely inorganic material. These soil movements do not seem to be occurring at the present time.

Similarly, the deep lithosols are not forming at present, nor the large patterned features associated with them. The development of these features is thought to require permafrost or deep seasonal freezing of the subsoil, conditions which do not occur on the high plains today (Washburn 1956).

This evidence indicates that periglacial conditions have operated intensively in the past in the development of the deeper lithosols and alpine humus soils. In fact, severe periglaciation is a corollary of the mildness or absence of glaciation on the Victorian high plains. The importance of such periglacial weathering is that subsequent soil formation and plant succession can be very rapid, since deep soil materials of usually favourable mechanical composition are already in existence (cf. Cotton and Te Punga 1955). Further implications are that the high plains provide an excellent hydrological system for the absorption and subsequent discharge of water, but that the risk of accelerated soil erosion is unusually high.

In the absence of absolute age determinations of the stony layers and other reference horizons, it is not possible to say when such periglacial conditions occurred. However, preliminary studies in similar areas of New South Wales and the A.C.T. suggest that periglaciation has been experienced more than once in the recent past. In the Perisher Valley at Kosciusko, a drained peat overlying a basal stony layer which appears to be co-extensive with a stony layer of alpine humus soils in the

area, has been dated at $8,100 \pm 250$ years. Most of the bog peats appear to be younger: the age of the large bog at Ginini (Costin et. al. 1959) is only $3,240 \pm 70$ years. Like many other currently forming bog peats it rests on a stony base and may indicate a still more recent periglacial phase.

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THE ROLE OF SHRUBS IN SOME PLANT COMMUNITIES OF THE BOGONG HIGH PLAINS

By STELLA G. M. CARR

Introduction

Many of those with a long acquaintance with the Bogong High Plains are of the opinion that shrubs have become more numerous there over at least the last 20 years. This observation has been shown to be correct by (a) comparison of the present-day distribution of shrubs with aerial photographs taken in 1938 (State Electricity Commission of Victoria) and 1945 (Department of Lands and Survey, Victoria, 1950) and (b) by measurements made over the period 1945-1959 (Carr and Turner unpublished data). The increase in shrubs (which are not grazed) at the expense of edible herbage is causing concern to some run-holders and is important from another point of view. On the alpine plateaux of the State, all of which show the tendency, vegetation in which shrubs are dominant or numerous presents a greater fire-hazard than does vegetation in which grasses and herbs predominate. Further, once they are burnt, shrubs are slow to recover and soil losses are severe and continue for many years. Shrub (or scrub) understoreys are also a current problem in the woodlands and forests of the slopes leading up to the high plains, but in this paper it is intended to deal only with the plant communities of the open tops.

Although the increase in the area occupied by shrubs has been considerable, not all of the plant communities have been affected by it. The mossbeds, the vegetation of which is predominantly woody, have certainly not extended. In the broad sweep of the herbfields, minute isolated shrubs persist, but are unable to make normal growth because they are trampled by grazing stock (Carr and Turner 1959). The same is true of the snow patches. On the other hand, many of the old-established shrub communities characteristic of rocky sites have become denser and have also extended at the expense of adjacent grassland and herbfield. In the grasslands and snow gum woodlands, isolated shrubs and clumps of shrubs have appeared in large numbers where shrubs were formerly few and scattered. In some cases, grassland has been replaced by continuous shrub communities.

The Shrub Flora of the High Plains

Excluding very rare species, the flora of the high plains consists of about 160 species of higher plants. Of these, 34 are shrubs, most of which are restricted to alpine and subalpine areas. Few of the other shrub species (wides) which also occur elsewhere in the State at lower elevations are of importance in the vegetation of the high plains. *Hovea longifolia* is very common on well-drained soils, particularly in grassland and snow gum woodland. It is an aggressive species and tolerates severe wind pruning. *Epacris paludosa* is confined to mossbeds but is a very common species in them. *Epacris microphylla* is a common species in herbfields at high elevations and also occurs on intermittently wet ground from about 5,400 ft upwards. The other species of the group are of widespread occurrence on well-drained sites but they appear only in situations which offer sheltered or

otherwise special conditions. None of them is aggressive. A list of the wides with notes on their field behaviour is given in Table 1.

TABLE 1

List of shrub species which occur on the high plains but are not restricted to alpine regions, with notes on their field behaviour

Species	High Plains	Lowland
<i>Epacris microphylla</i> R. Br.	On intermittently wet soil from 5500 ft upwards; also in herbfield at 5800 ft and upwards	Wet heathland
<i>E. paludosa</i> R. Br.	Mossbeds	Wet heathland
<i>Hovea longifolia</i> R. Br. in Ait. f.	General distribution on well-drained soils, very common in grassland and woodland. Tolerates wind-pruning.	Widely distributed in mountainous country
<i>Hymenanthera Dentata</i> R. Br. ex DC. var. <i>angustifolia</i> (R. Br. ex DC.) Benth.	General distribution on well-drained soils, common, but never seen in well-grown state. Occurs as dwarf, straggling plants among snow grass or as unthrifty espalier.	Widely distributed but chiefly riparian
<i>Pimelca axiflora</i> F. Muell. ex Meissn. var. <i>alpina</i> F. Muell. ex Benth.	Snow gum woodlands and grassland. Tolerates moderate wind-pruning.	Wet sclerophyll forests
<i>P. ligustrina</i> Labill.	Only in sheltered places, sometimes riparian.	Riparian and in wet sclerophyll forests

The shrub species which are restricted to the high plains can be arranged in a series according to the wetness of the soils they occupy (Table 2). It is not proposed to deal here with the shrubs characteristic of the mossbeds but to consider only those characteristic of better-drained and drier soils.

Characteristics and Field Behaviour of Shrubs

The species concerned have many features in common. Their leaves are small, thick and entire and on old shoots they are restricted to the upper parts of the stems where they are aggregated to form a dense canopy which varies in depth with the species. Immediately below the canopy there are usually many thin, dead branches but the lower portions of the stems are bare. Although in the field the shrubs are slow-growing and much-branched from the base, in cultivation they assume a single-stemmed habit. Only two species (*Hovea longifolia* and *Kunzea muelleri*) have been seen to produce roots from stems in the field. These will be referred to as 'rooting' species and the others as 'non-rooting'. In all species, if the upper parts of the plants are damaged or removed, new shoots grow out from the base of the stems.

The performance and shape of shrubs is much affected by wind-pruning. The prevailing wind is NW. and in all but the most sheltered positions isolated shrubs, clumps of shrubs and whole shrub-communities have uniform, dense canopies. Isolated shrubs and small clumps have a smooth, rounded profile. The rate of growth in height depends largely on the extent to which the plants are exposed to the prevailing wind. This may be illustrated by the following data for two species

neither of which tolerates extreme exposure. *Bossiaea foliosa* plants 18 years old, growing in a sheltered situation were 42 in. tall. Plants of the same age on exposed sites were between 12 and 15 in. in height. *Phebalium podocarpoides* plants growing in shelter ranged from 15 to 24 in. tall while those of the same age growing on exposed sites were between 10 and 12 in. high. At elevations of 5,400-5,800 ft shrubs well-established in grassland commonly project above the sward, but at higher elevations on NW. slopes any shrubs present (and they are often very numerous in herbfield vegetation at these altitudes) produce their wind-pruned canopies at the level of the top of the sward. They are capable of maintaining dense canopies only if the vegetation of the windward side remains intact. If the shelter is removed the branches on the windward side of the shrub die and the other branches become denuded of leaves except at their tips. On the eroded mountain tops characteristic of the alpine region shrubs grow very slowly and assume a prostrate habit. In the lee of rocks or tussocks growth is still slow but the stems are more leafy. The most successful species in such situations is *Kunzea muelleri*. It grows flat on the soil with its shoots parallel to one another and directed downwind.

The stems of all species are readily damaged by bruising. Branches so damaged usually die, possibly from excessive water loss through breaks in the cortex. The commonest cause of bruising is trampling by stock but similar effects can be produced by motor vehicles (Pl. XXXVIII, fig. 2). The most severe damage occurs where shrubs spread over rocky or eroded ground. The persistence of vehicle tracks, some of which were used only a few times many years ago, is readily perceived but the extent to which shrubs and shrub communities are affected by the trampling of cattle is not generally appreciated. In an earlier publication (Carr and Turner 1959) it was shown that trampling prevents the development of shrubs in herbfield communities of Pretty Valley. The effect of trampling on scattered shrubs is also shown clearly by comparison of the adjacent fenced and grazed areas at the NE. corner of the Rocky Valley plot. The enclosed area has been protected from stock since 1945. The increase in the size of the shrubs and the amount of shrub cover is not due to lack of grazing, as none of the shrubs is eaten by cattle.

Regeneration from Seed

Most of the shrub species produce considerable quantities of seed with some regularity. Most species shed their seeds in the same season in which they are formed, others early in the following season. In most species the seed falls free of the fruit walls, notable exceptions being those of *Leucopogon* spp. and *Lissanthe montana*. Preliminary investigations have shown that not all species require a cold treatment for germination. Seedlings of the majority of species have been recorded in the field during 1941-1959 but very few have been seen at any one time. Whether or not they are more numerous after fire is not known. Protection from stock (1945-1959) has not resulted in any marked increase in numbers of seedlings although it does affect their chance of survival. Seedlings have never been observed growing together in large numbers. If they occur at all they are solitary or very widely spaced.

The very numerous ants (many of them harvesters) of the high plains may considerably reduce the numbers of seeds available for germination but it must also be taken into account that as seedlings can only establish on bare ground very considerable losses must occur between germination and establishment. At these elevations patches of bare ground constitute a difficult environment for ecesis. None of the perennial grasses and only one or two unimportant species of herbs can

colonize bare ground by other than vegetative means. In fact, vegetative propagation is a far more widespread phenomenon than seedling regeneration in this area. Regeneration of shrubs from seed is much affected by competition from established grasses, herbs or other shrubs. It follows that patches of bare ground below a certain minimum size (about 4 in. in diameter in most communities) are not colonized by shrubs. On the other hand, shrubs appear to have difficulty in becoming established on large patches of bare ground in windswept situations. Records have been kept of patches of bare ground (3-4 ft in diameter) which appeared after the 1939 fires and on which no seedlings of any kind have appeared. These patches are on NW. slopes at 5,600 ft. Some have been protected from stock, others not. Adjacent smaller patches of bare ground 9-15 in. in diameter, formed at the same time, have been colonized by shrubs. It appears that the amount of shelter provided by the grass sward, 4-6 in. high, which surrounds these smaller patches is sufficient to allow shrubs to become established.

The Regeneration Cycle

The course of development followed by a seedling shrub or by the shoots which may arise from the crown of an older shrub, the overground parts of which have been destroyed, depends to a great extent on three factors. They are (a) the amount of competition, (b) the degree of wind-pruning, and (c) the amount of damage suffered during growth.

If competition is severe the young shrub is likely to remain dwarfed and suppressed by grasses, herbs or by other shrubs. Throughout the whole area it is common to find straggling, suppressed shrubs in apparently pure grassland and the majority of well-grown shrubs harbour suppressed individuals of at least one other shrub species. The suppressed shrubs grow very slowly but are nevertheless capable of surviving for at least 20 years. Watt (1947, 1955) has pointed out that, in the development of a shrub, certain phases may be recognized on the basis of characteristic changes in its morphology and vigour. On the high plains, if a young shrub is not subjected to severe competition, and if wind-pruning is moderate, its development follows the pattern described by Watt (1955) for *Calluna vulgaris*. It will increase in size through the pioneer and building phases until it reaches maturity. Maturity is followed by a phase of degeneration and in the extreme by death. Re-establishment by seed or by vegetative means may or may not follow. The canopy remains dense until maturity and as it extends laterally, already-established plants of grasses and most herb species become shaded and completely suppressed. However, once the shrub is well-grown the shelter provided by its canopy allows grass seedlings to become established.

Once the stage of maturity is past most shrubs become flat on top. The central, erect branches eventually lose vigour, become much less leafy and then die, leaving an opening in the centre of the shrub (Pl. XXXVIII, fig. 1). The opening enlarges centrifugally by the death of further branches. The dead branches fall outwards so that they come to lie over and among the living ones. Shrubs in the advanced degenerate phase commonly take on a bowl- or saucer shape. Ultimately only the prostrate branches remain alive. Their stems become overgrown by other plants and only the upturned ends bear leaves. The old shoots or 'non-rooting' species eventually die but the shoots of 'rooting' species keep on growing, their vigour depending on the severity of competition.

During the life-cycle of a shrub special environments exist beneath its canopy. The effect of a shrub in ameliorating the general conditions, small at first, increases as it grows to maturity. It then exerts a considerable control over the light intensity,

the wind speed and humidity beneath its canopy. The accumulation of litter is also favoured. Under well-grown shrubs seedlings of *Poa caespitosa* G. Forst. (snow grass) and, less commonly, ledge grass (see Carr and Turner 1959) are extremely common in many seasons. Where the shrub canopy is dense (building and mature phases) the seedlings die when they are about one inch high, but as the canopy of a shrub begins to thin out, and with the onset of the degenerate phase, grass seedlings at the centre of the base of the shrub persist and grow slowly into 'leggy' weak plants, with long leaf-blades which are much less rigid than those of older plants growing under open conditions. By the time the opening in the canopy is well-defined the grass plants colonizing it have formed small but dense and vigorous tussocks. Colonization by the grass and growth of the tussocks keeps pace with the enlargement of the opening in the shrub canopy so that after a few years the whole area previously covered by the shrub may have become occupied by grass. During this process shelter is afforded the grass by the remaining parts of the shrub.

Where conditions are favourable for the development of grass there is no immediate opportunity for the re-establishment of 'non-rooting' shrubs but, as explained earlier, 'rooting' species may persist in a suppressed state. The establishment of grass in the gap phase of shrub development initiates another cycle of development similar to that described for shrubs. However, by the time the grass has reached the late degenerate and gap phases of its life history, or when a patch of grass is killed by insects (Carr and Turner 1959), the soil surface is covered by a mat of litter, 2 to 6 in. thick. Unless this litter is disturbed no opportunity is provided for the establishment of shrubs from seed. In the normal course of events the grass re-establishes itself by the development of new tussocks from surviving shoots and/or from seed. It takes several years before the grass again provides complete cover. In the meantime herbs grow vigorously in the absence of competition from the grass but are readily suppressed as the tussocks enlarge. Any small shrubs which were present in the original sward also show a marked response to the absence of competition and some individuals may enlarge to such an extent as to shade the grass around them. They thus become dominant and then maintain dominance until they reach the degenerate phase, when an opportunity is again presented for colonization by grass. It must be emphasized that the only time in the life-history of a shrub during which grass seedlings can progress to the tussock-forming stage is during the degenerate phase. A shrub in any earlier phase is proof against invasion. It should also be noted that, although in favourable seasons minute seedlings of grass occur on bare ground they do not persist (Carr and Turner 1959). They are able to grow into tussocks only where shrubs, acting as a nurse crop, provide suitable conditions for their continued development.

The cycle of events just described may be affected by special features of the site. On very immature soils and in places where soil erosion has been severe, formerly suppressed shrubs may grow up to fill the opening which develops in the canopy of the degenerate 'host' shrub. Any grass plants which may have been present are suppressed and eliminated. It is assumed that conditions which allow the development of grass tussocks will not recur until the second-generation shrub becomes degenerate. In fact, in some areas it may take several generations of shrubs to build up the soil to the point where it can support a sward of grass.

On very exposed sites where wind-pruning restricts the height of the shrubs to less than one foot the cycle may follow a somewhat different pattern. In an earlier publication an account was given (Carr and Turner 1959) of the relationship between a rosette herb, *Celmisia longifolia* and three shrub species restricted in height to about 7 in. Briefly, *Celmisia* rhizomes colonized the ground under the

shrubs, its leaves grew up through the canopies before any obvious openings occurred and expansion of the rosettes breached the shrub canopies. In 1959, suppression of shrubs only 11 years old was well-advanced.

In parts of the high plains wind-pruning is not an important factor. On steep E. and S. facing slopes the effects of wind may be very slight and elsewhere small areas are sheltered by large rocks. These areas are usually in snow gum woodland so that additional protection is given by the trees. In such sheltered sites, isolated shrubs are wider and taller than their counterparts in the open. It is more usual to find areas of this kind occupied by closed communities of shrubs. The opportunity for establishment of large numbers of shrubs from seed and the rejuvenation of old shrubs was very great after the 1939 fires when much of the grass cover was destroyed and large areas of bare soil were created. In the first few years the shrubs grew in association with and in increasing competition with the surviving grass plants. The communities were mixed and still open in 1945 and even those subsequently protected from stock remained open until about 1950. Since then enlargement of the shrubs has enabled them to form a closed community. The grass has been suppressed and the shrubs have entered into severe competition with one another. As a result they have grown into tall, elongated plants the individuality of which is not immediately apparent. In some areas such shrubs were as much as 5 ft high in 1959. In these dense stands of shrubs the pattern of orderly development is not as readily apparent as it is in open communities or those in which the shrubs are smaller. On close examination it can be seen that the central branches are losing vigour and that the plants, in fact, are following the normal pattern of development and degeneration. A continuous cover of grasses will probably not develop with the death of the present generation of shrubs in these closed communities as, on the areas they occupy, soil erosion following the 1939 fires was severe. With the death of the existing shrubs grass will probably establish on some of the area, reducing the space available for shrub regeneration. With succeeding generations of shrubs the balance will most likely be tipped more and more in favour of grassy vegetation.

Length of Cycle

It was reported earlier (Carr and Turner 1959) that, except in herbfield where special conditions apply, shrub plants commonly take at least 18 years before they show distinct evidence of degeneration. Further observations have confirmed this. *Prostanthera cuneata*, *Phacelium podocarpoides*, *Hovea longifolia* and *Grevillea australis* growing on sites where wind-pruning is moderate usually have a central opening in the canopy when they are 18 to 20 years old. *Grevillea australis* when growing on more exposed sites, often has an intact canopy at 20 years. There is some suggestion that for those species which can tolerate severe conditions, constant wind-pruning may have the effect of maintaining the plant in a vigorous condition and thus prolonging its life beyond that on more sheltered sites. *Orites lancifolia* also tolerates severe wind-pruning and some very large specimens on exposed situations have branches which in 1957 were at least 40 years old. The canopies showed no obvious gaps. Under less severe conditions *Orites* is still longer-lived than the species mentioned above. Many plants known to be 20 years old are still vigorous.

The Effects of Trampling

Seedlings at the cotyledon stage are readily destroyed by trampling. Death may result from damage to the shoot or from disturbance of the soil around the root.

Older plants are more resistant but may also be killed by repeated damage (Pl. XXXVIII, fig. 2). From the point of view of maintenance of ground cover any considerable damage to the overground parts of shrubs is serious as dead branches are replaced only very slowly. A comparatively small amount of damage involving the loss of one or two branches may have far-reaching effects because a breach in the canopy of a shrub growing in a wind-swept situation may cause it to lose the smoothness of its aerodynamic profile. The turbulence associated with the opening may be sufficient to cause the partial or complete destruction of the rest of the canopy. Extensive damage to the canopy reduces the microclimate beneath it to a less favourable state, prevents the accumulation of litter and exposes bare ground. It sets the shrub back in development to an earlier stage in its life-history—usually the pioneer phase. This delays the onset of those phases in which replacement by herbaceous species becomes possible. Up to a certain point damage therefore favours the persistence of shrubs. Beyond this point the shrubs cannot make good their losses and die. When they do so bare ground is exposed. In herbfield, the patches of bare ground persist until they are colonized by either shrub seedlings or by a herb (e.g. *Leptorrhynchus*) which spreads by vegetative means (Carr and Turner 1959). In all the other communities under consideration shrubs are the only effective colonists of bare ground, and the open patches persist until seedlings become established or 'rooting shrubs' overgrow them. It is necessary to point out that, although a shrub in the mature phase of its life history may escape damage because it is not attractive to stock and is too tall for them to walk through, once tussocks develop at its centre it is likely to be trampled by stock attempting to graze the grass.

The Incidence of Fire and Its Effects on Shrubs

All the available evidence suggests that fire was not an important factor in the area before 1939 (Carr and Turner 1959). This is due, at least in part, to the fact that the grasslands and herbfields do not burn readily. If, however, grasses and herbs are burnt the damage is usually superficial. The bases of the plants and the litter surrounding them remain undisturbed and recovery is rapid. On the other hand, because shrubs burn more fiercely than herbaceous plants, it is common to find that the litter under them burns with the canopy. As recovery is slow, any litter which remains is exposed to the wind and the lighter material blows away. It is therefore common to find that much bare ground is exposed after a shrub community has been burnt. The same is generally true of snow gum woodland. When shrubs isolated in otherwise herbaceous vegetation burn they have the effect of making the fire locally more severe and hence increasing the damage suffered by the sward around them. The size of the patch of bare ground which results is therefore larger than the area originally occupied by the shrub.

In most instances damage to shrubs by the 1939 fire affected only the overground parts and regeneration took place from the base. In some places (the S. side of Mt Cope and on the upper part of Frying Pan Spur) the fire was very severe. Many shrubs were killed and their charred stumps have shown no regeneration.

Conclusions

The plant communities of the high plains consist of grasses, herbs and shrubs in varying proportions. Although it is normal for shrubs to occur in all the communities, study of the least-disturbed examples of each kind of community suggests that shrubs are naturally at a minimum on soils which have a deep A horizon and are well-drained. On the other hand, they become prominent in most of the

communities which occur on sites where the water table is high for at least part of the year and also on well-drained sites where the A horizon is shallow (around rock outcrops and on very stony sites). For these and other reasons, it appears that under natural conditions, the presence of shrubs indicated immaturity of the plant communities and of the soils on which they occurred,

From what has been said earlier, it is obvious that on well-drained sites on the high plains there is a natural tendency towards reduction in the amount of shrub cover, because if shrubs are allowed to develop freely they provide conditions which favour the development of grass and not the perpetuation and spread of shrub communities. Wherever snow grass occurs in the area, the soil beneath it shows a complete profile and the A° and litter layers are well-developed. The soils on which shrubs grow do not show this uniformity. In some cases, the soil profile appears to be complete and to have suffered no disturbance, but in other cases, the shrubs are rooted in hollows which lie below the level of the surrounding soil. In the hollows the soil profile is truncated. The litter and A° horizons characteristic of grassland and some of the A horizon are lacking. All gradations between these two extremes may be observed. It appears then, that shrubs may develop in grassland in response to both slight and very severe damage.

Slight disturbance may involve interference with the vegetation only to the extent that the ability of the grass to compete with herbs and shrubs is reduced, but it also includes disturbance of, and removal of part or whole of the litter and A° horizon. Severe damage involves the A horizon of the soil. Slight disturbance is most likely to give rise to rapid alteration in the grass-shrub ratio in communities growing on immature, shallow soils because there the balance between grass and shrubs is delicate. The grass cannot invade and persist on the ground occupied by shrubs unless very special conditions are fulfilled but, on the other hand, if the competitive power of the grass is reduced, the shrubs can encroach on the area occupied by the grass and retain their dominance for many years. Herbs are relatively unimportant in such communities.

On deep mature soils where shrubs are naturally few, shrub dominance takes much longer to develop and, if the damage is slight, shrub dominance is preceded by a stage in which herbs increase in importance. The grass may suffer damage which hinders its development at any stage of its life-cycle, but the most severe and rapid effects result from disturbance during the degenerate phase. The regeneration cycle associated with the life history of the grass involves the intervention of herbs (chiefly *Asperula gunnii* Hk. f.) at the degenerate phase. Once the grass is re-established the herbs are again reduced to insignificance. Under normal circumstances (i.e. those in which there is no disturbance of the dead grass and litter and the grass re-establishes quickly) shrubs take no part in the cycle. Any suppressed shrubs which may be present in the sward grow a little in response to the absence of competition but this is insufficient to allow them to escape severe competition when the grass is re-established. The persistence of very old dwarf shrubs in relatively undisturbed grassland indicates the effectiveness of the control exercised by the grass, the life-cycle of which occupies a much shorter period (approximately 10 years) than that of the shrubs. Disturbance of the dead grass and litter and A° horizon tends to increase the herb component of the sward. It also allows any suppressed shrubs to grow freely so that eventually they may assume local dominance, but it does not provide the conditions necessary for the establishment of shrubs from seed. However, if the disturbance involves actual loss of soil, shrub seedlings may develop, depending to some extent on the community affected.

Shrubs are an important element in the vegetation of the area, if only because of the part they play in the repair processes which are initiated once damage has occurred. The extent to which they are necessary for the regeneration of the vegetation depends on the severity of the previous damage and soil erosion, but their present state of development depends on the amount of trampling, past and present. In those communities which are heavily grazed the trampling factor is sufficient to make the survival of existing shrubs precarious and the establishment of others unlikely, even though there is much bare soil available for colonization. In other communities, less heavily grazed, where shrubs are naturally abundant or have become established following damage, trampling prevents the completion of their life cycle. The immediate result is that in many cases a lack of adequate protection for the soil under and around shrubs. The long-term consequence is that completion of the shrub cycle and, with it, the replacement of woody by herbaceous vegetation, is prevented or indefinitely delayed.

The cure for this is closing the whole area to grazing. One important response to this treatment would be a very great increase in the number and size of the shrubs in the area because (a) shrubs are the only plants which can initiate regeneration in much of the area, and (b) in many of the communities shrubs are already established but are unable to grow normally because of trampling. However undesirable unrestricted growth of shrubs may appear in the short term view, it is essential that it should take place. The free development of shrubs is necessary for the establishment of vegetation on eroded soil and for re-establishing predominantly herbaceous vegetation on the very large area of the high plains which is capable of supporting it.

TABLE 2

List of species confined to alpine and subalpine areas and which occur on the Bogong High Plains, arranged according to usual habitat

1. Well-drained sites (grasslands, snow gum woodland, herbfield) :
 - (a) often associated with rock outcrops and rocky slopes, but not confined to them—
Drimys xerophila Parment. (usually only in woodland)
Orites laucifolia F. Muell.
Oxylobium alpestre F. Muell.
Phacelium phyllicifolium F. Muell.
 - (b) grassland, herbfield only—
Pimelea biflora Wakefield (very rare)
 - (c) of general distribution (* indicates that the species is common on windswept sites)—
Bosiaca foliosa A. Cunn
**Grevillia australis* R. Br.
Hclichrysum alpinum Wakefield
**Lcucopogon hookeri* Sond.
**L. montanus* (R. Br.) J. H. Willis
**Olearia algida* Wakefield
O. frostii (F. Muell.) J. H. Willis
O. phlogopappa (Labill.) DC. var. *subrepanda* (DC.) J. H. Willis
Oxylobium ellipticum R. Br.
Pimelea alpina F. Muell.
**Phacelium podocarpoides* F. Muell.
**Picurandropsis trymalioides* F. Muell.
Prostanthera cuneata Benth.
2. Sites on which soils alternate between very wet and dry, very shallow mossbeds and poorly-drained soils in depressions :
Epacris petrophila Hk. f.
Exocarpos nanus Hk. f. (rare)
Kunzea muelleri Benth.
Pentachondra pumila R. Br.

3. Damp well-drained soils at the foot of slopes:
Olearia phlogopappa (Labill.) DC. var. *flavescens* (Hutch.) J. H. Willis
Helichrysum hookeri (Sond.) Druce
4. Mossbeds:
Backea gummiana Schau.
Callistemon sieberi DC.
Exocarpos nanus Hk. f.
Pultenaea fasciculata Benth.
Richea continentis Burt
5. Riparian or among rocks where water is available at depth:
Podocarpus lawrencei Hk. f.

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Explanation of Plate

PLATE XXXVIII

- Fig. 1—Central gap in the canopy of plan of *Prostanthera cuneata*. The shrub is 18 years old and has been protected from stock 1945-1957 on the Rocky Valley Plot. (Photograph by courtesy of Mrs L. B. Thrower)
 Fig. 2—Dead branches of shrubs on main cattle-track, photographed 1951. The track was much used until 1945, but has since been more or less neglected except for grazing stock. Regeneration of shrubs is very slow.



ZOOLOGY OF THE HIGH PLAINS: PART I—ICHTHYOLOGY AND HERPETOLOGY

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Our knowledge of the fish, amphibians and reptiles of this area is fragmentary and the literature records are scattered. Thus this account should not be considered complete in any way. The fauna of the adjacent Monaro Region of New South Wales is better known, and since it is effectively continuous with the eastern highlands of Victoria it seems logical to consider it also.

PISCES

Only one indigenous family of fish (Teleostei : Galaxiidae) is known to occur in the mountainous regions of south-eastern Australia. One species has been recorded from such habitats in Victoria.

GALAXIIDAE

Galaxias coxii Macleay

Localities: L. Tarli Karng (= L. Nigothoruk), altitude 3,100 ft on Mt Wellington (Lucas 1892, Regan 1905, Mack 1936); confined to the mountainous country E. of Port Phillip Bay (Mack 1936); Bogong High Plains (Garnet 1959).

The New South Wales distribution of this species is described as the mountains and highlands of the Great Dividing Range, excepting the southern portion (Stead 1906). The type locality in Mt Wilson, N.S.W., c. 3,500 ft (Macleay 1881).

A second species, *G. findlayi* Macleay, occurs on the highlands of the Monaro and Snowy R. Districts of N.S.W., particularly in the neighbourhood of Mt Kosciusko (Stead 1906). This species was described from specimens collected in icy ponds on the snowy range in the vicinity of Mt Kosciusko (Macleay 1883). Tadgell (1930) collected specimens of *Galaxias* in the Pretty Valley (altitude 5,600 ft) on the Bogong High Plains. These were identified as *G. findlayi* by J. A. Kershaw. Since later collections from this area have been identified as *G. coxii* (Garnet 1959), and because *G. findlayi* appears to be restricted to the Monaro Region while *G. coxii* is widespread, it would be desirable to check Kershaw's identification.

AMPHIBIA

Four species of anurans in two families occur at altitudes above 4,000 ft in Victoria.

LEPTODACTYLIDAE

Crinia signifera Girard

Localities: Rocky Valley Reservoir, c. 5,000 ft, on the Bogong High Plains (M.J.L.), Lake Mountain at 4,200 ft (M.J.L.).

This species has also been collected as high as 6,500 ft on Mt Kosciusko, N.S.W. (Parker 1940). It is a wide-ranging and common species at lower altitudes.

***Crinia laevis* Günther**

Locality: Lake Mountain at 4,200 ft (M.J.L.).

One egg mass and a number of tadpoles, almost certainly of this species were collected at the above locality. Some of the tadpoles were reared through metamorphosis. The slight doubt concerning their identity arises from the difficulty in identifying recently metamorphosed frogs. *Crinia laevis* also occurs commonly at lower altitudes in southern Victoria.

***Philoria frosti* Spencer**

Locality: Mt Baw Baw (Spencer 1901).

This frog has been collected by the author (M.J.L.) above 4,000 ft at the same locality. It appears to be restricted to Mt Baw Baw.

Another alpine species of N.S.W. is *Pseudophryne corroboree* Moore. It is found in the Kosciusko and Brindabella regions (Moore 1961) as high as 5,680 ft, and is believed to be restricted to high altitudes.

HYLIDAE

***Hyla ewingi* Duméril and Bibron**

Localities: Mt Baw Baw (Copland 1957); Bogong High Plains (Garnet 1959); Lake Mountain at 4,200 ft (M.J.L.); Rocky Mountain Reservoir, c. 5,000 ft, on the Bogong High Plains (M.J.L.); Mt Buller Village area, c. 5,300 ft (M.J.L.).

Hyla ewingi has also been collected at 6,500 ft on Mt Kosciusko (Moore 1961). It is a common species at low altitudes.

REPTILIA

Species in two families of lizards and one family of snakes have been recorded from high altitudes in Victoria.

LACERTILIA

AGAMIDAE

***Amphibolurus diemensis* (Gray)**

Locality: Mt Wellington, 'met with amongst rocks at considerable elevations in the mountains' (Lucas and Frost 1894, as *angolifer*).

SCINCIDAE

***Sphenomorphus quoyii* (Duméril and Bibron)**

Locality: Bogong High Plains (Garnet 1959).

***Leiopisma entrecasteauxii* Duméril and Bibron**

Locality: Mt Baw Baw (Lucas and Frost 1894).

***Leiopisma pretiosum* O'Shaughnessy**

Locality: Mt Baw Baw (Lucas and Frost 1894).

Copland (1947) lists 6 species of lizards from heights above 5,000 ft on Mt Kosciusko, N.S.W. They are: *Amphibolurus diemensis*, *Tiliqua casuarinae* (Duméril and Bibron), *Egernia whitii* (Lacépède), *Sphenomorphus quoyii*, *Leiopisma entrecasteauxii* and *Hemiergis decresiensis* (Fitzinger). Costin (1954) cites Copland's records plus 2 others: *Amphibolurus muricatus* (Shaw) and *Diplo-*

dactylus vittatus Gray from the alpine and subalpine zones of the Monaro Region of N.S.W.

OPHIDIA

ELAPIDAE

Denisonia superba (Günther)

Locality: Bogong High Plains (Garnet 1959).

Denisonia coronoides (Günther)

Locality: Pretty Valley, Bogong High Plains (Garnet 1959). Pretty Valley has an altitude of 5,600 ft.

These 2 species are also recorded from above 5,000 ft on Mt Kosciusko by Copland (1947).

One other record which should perhaps be noted is that of Spencer (1901) who writes that the first specimens of *Philoria frosti* were taken from a snake (*Hoplocephalus curtus* = ? *Denisonia curta* Schlegel) on Mt Baw Baw.

Acknowledgement

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ZOOLOGY OF THE HIGH PLAINS: PART II—BIRDS AND MAMMALS

BIRDS (BIBLIOGRAPHY) AND MAMMALS

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Birds

Virtually no collecting of bird specimens has been done on the Victorian high plains. Since 1900, however, a number of papers and notes relating to field observations of birds at various high plains localities have been published in natural history and ornithological societies' journals. Birds are a popular study for the field naturalist. As a result the ornithologist at once reaps the benefit of other people's observations and the problem of assessing their reliability.

To ignore field records that are unrelated to collected specimens as a general principle would be to disregard a large part of ornithological literature. In well-worked areas, where observers are numerous, field lists are constantly subjected to the critical examinations of experienced observers and most errors are ultimately corrected. No such safeguard can yet be claimed for an area as little studied as the high plains.

The present paper has two aims:

- (a) to draw attention to the meagreness of existing information on the bird life of the area;
- (b) to initiate a bibliography relating to the avifauna of the Victorian high plains as elsewhere defined.

With regard to the first of these aims, one or two points which emerge from perusal of published notes promote comment. The area in which most observations have been made is, not unexpectedly, Mt Buffalo Plateau. In all published notes the species for which records are claimed are chiefly common ones that are typical of grassland, woodland, and sclerophyll forests of lower altitudes. There is nothing to suggest that the relatively very small part of Australia falling within the Victorian high plains definition is, or has been, a centre of bird speciation. It is not to be expected that any bird species will be confined to the high plains. Some subspeciation, or at least altitudinal variation may occur but this can be determined only by collecting.

The classification of vegetation types outlined by Beadle and Costin (1952) seems very suitable for use in recording bird habitats. It is hoped that a terminology for alpine bird habitats acceptable to botanists in terms of vegetation types can be agreed upon and that future observers will use it in recording existing bird habitat relationships.

Concerning the second aim, it should be understood that the present short bibliography in no way aspires to completeness but is intended as a basic list. The author would welcome critical comment, additional references, or guidance to other lists whether published or not. Acceptance of species records by any author is not to be inferred by inclusion of the reference in the bibliography.

It is trusted that the authors included will not mind the critical atmosphere in which their contribution is listed but will recognize that knowledge of birds of the region is still in the 'melting pot' stage.

Mammals

Victorian mammalogists advise that so far there are no scientifically acceptable records relating to the high plains. References to such species as the fox, dingo, and wombat occur in popular literature. Unlike ornithology, mammalogy has not enjoyed the assistance of societies devoted to the study of its own animals and providing a core of general knowledge which ensures some degree of reliability in field records. There is, therefore, a striking need for both collecting and reliable field recording of mammals on the high plains.

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THE ABORIGINES OF THE VICTORIAN HIGH PLAINS

By ALDO MASSOLA

Introduction

The scattered information about the aborigines formerly inhabiting the Victorian high plains is here brought together. No particulars, however insignificant they may seem to be, have been omitted, and no personal embellishment or supposition has been added. The sources of information are in the bibliography at the end of the paper.

Historical

The high plains were discovered in 1824 and occupation begun in 1839. In that, and the following year, the natives gave some trouble, e.g. the Faithfull massacre, cattle stealing, attacks on outstations, etc. In 1852 gold was discovered, and an avalanche of Europeans and Asiatics poured into the high plains. The aborigines were engulfed and simply disappeared. By 1862 only four, with a doubtful fifth, remained.

Up to this period no record of aboriginal life appears to have been collected. It was not until 1895 that Helms gave the first published account of the natives. His information was obtained from 'old settlers'. The next author was A. W. Howitt, in 1904, whose information had come from an aboriginal woman whose name he does not give. It is obvious that much of the ceremonial life would be unknown to her. The last two aborigines of the high plains were two women: Black Mag, who died of exposure after a drunken bout at Corryong in 1883, and Charlotte, who died in the 1890's. It is possible that Howitt's informant was one of these.

The third, and last recorder was R. H. Mathews, who surprisingly claims to have received his information while 'journeying amongst the remnants of the tribes' subsequent to 1898. Writing in 1909 he agrees in a broad sense with the former authors, although his name for the tribes differs considerably from the other two.

According to Howitt, the aboriginal inhabitants of the Victorian Tablelands called themselves Ya-itma-thang. The tribal name was derived from the affirmative, in this case, 'Ya-yau', = yes, to which was affixed 'Thang', speech or tongue. That is, they were the people speaking the language which said 'Ya' for Yes.

The Ya-itma-thang occupied the lower plateaux all the year round, and visited the higher tablelands during the spring, or as soon as the snows had melted, and during the summer months. They were divided into two sections, of which one, the Theddora-mittung, occupied the country around the sources of the Mitta-Mitta and its tributaries down to the Gibbo Mt, and the upper Kiewa and the Ovens up to Mt Buffalo. The other section, the Kandengora-mittung lived on the Omeo plains, along the Limestone R. to its junction with the Indi, and along the Tambo to Tongio-mungie. The word 'mittung', affixed to their tribal name, means Men ÷ thus Theddora-mittung = Theddora — men.

The Ya-itma-thang were on friendly terms with the Ngarico of Monaro, and the Wolgal, who ranged as far north as Queanbeyan. Their traditional enemies were the Kulin of central Victoria, the Twofold Bay natives, the Kurnai of Gippsland and

the Murray tribes below Albury. In short, it seems that while friendly towards other highland people they were at war with the tribes of the plains.

Mathews, though broadly agreeing with this version, has a different name for the tribe, which he calls the Dyinningmiddhang, and divides it into two linguistic groups, the Dhudhuroa and the Minyambuta, whose territory roughly corresponded to Howitt's Theddora-mittung and Kandengora-mittung.

Government

The oldest man of the tribe was recognized as chief, but in time of war main authority rested with the ablest warrior, who was automatically obeyed and his advice followed even by the elders.

The Family and Marriage Rules

The Ya-itma-thang had the two-class system of marriage, in which males of one class had to marry females of the other. A girl was promised as soon as born and given to her husband when mature. This practice was controlled by the rule that a man married the daughter, own or tribal, of his mother's brother. Descent, according to Howitt, was through the females, while Mathews states that it was only the northern group who had female descent, and that the southern group had descent through the male.

It sometimes happened that a girl would elope with a man other than the one she was promised to, or the one she could legally marry. In this case they were pursued, and if caught would be severely beaten. If sexual intercourse was contracted outside the marriage rules the punishment would be death. Adultery was punished in the same way.

It was not considered adultery for a brother to have sexual intercourse with his brother's wife, and during the absence of the husband the nearest of kin had marital rights with the wife or wives. The husbands of two sisters were considered to be brothers. Polygamy was customary, and the man who had the most sisters or daughters would naturally have the most wives, as he would have a better chance of obtaining these by exchanging the one for the other. Women could also be freely given as gifts, although remuneration was at times made by handing over weapons and other useful utensils.

Young people were strictly forbidden to have sexual intercourse, and would be severely beaten if caught. The sexes were kept separated from an early age. During her menses, a woman would bind a string around both arms to signify her condition. At the time she would be considered 'unclean', viz. if she crossed a stream no one would drink from this stream below her crossing place.

Birth and Childhood

Usually, as her time was approaching, the woman would retire to a secluded spot, and manage her confinement without any assistance. The child would be named after some special locality at or near which he or she was born, or after something unusual happening at that time. Children were allowed a great deal of freedom, but were taught obedience. This was enforced by threats of visits from evil spirits, who would cause them to contract diseases which would eventually kill them.

Initiation

At about the age of 14 to 16 years the boy would have one of his upper central incisors knocked out. This ceremony which lasted some days would make the boy a youth, or 'Kurrunong'. At the age of 18 or 20 he would be made a man, or warrior,

'Wahu', by the performance of another protracted ceremony from which women were excluded. Here, all the hair of his head was slowly singed off with a burning brand. Later, three men would join the ceremony waving green boughs in certain directions, at the same time uttering the name of the district or tribe living in that direction. Each name was prefixed by the exclamation 'Wau-Wau', and in the case of enemy groups followed by imprecations. This was to indicate to the newly-made 'Wahu' with whom he was to be friendly, and who were his foes.

At the conclusion of this ceremony women were again permitted to be present and the newly-made 'Wahu' had the right to choose one from amongst their number for that night, but that night only, always providing that she was of the right marriage group.

Neither circumcision nor subincision was practised by the Ya-ithma-thang.

The Ya-itma-thang used the bull-roarer during their ceremonies. This was swung in order to keep women and uninitiated men away. They were led to believe that the thundering noise was the voice of Papang, the All-Father, who had come down from the sky to make the boys into men. This belief in an All-Father is all that has been recorded of their religion.

Initiation of Girls

At the first signs of her first menses the girl was taken into the bush by some old women. Here her arms were bandaged with strips of possum skin, and her body anointed with possum fat and powdered charcoal. Next she was lifted on to the fork of a tree six or eight feet from the ground, and a fire of green boughs lit under her. This smoking process would last some hours, and often was repeated the next day or two. Following the smoking the girl was given a pubic fringe to wear, and was then considered marriageable.

Messengers

Messengers were sent to summon friendly tribes to a ceremony or to war against a common enemy. Two messengers generally went together so that one could sleep whilst the other kept guard over him.

Decorations

When at war or during ceremonies the men would decorate their bodies with paint. The colours used were white, red and black, The white was obtained from pipeclay, the red from raddle (red ochre) and the black was charred seedstalks of the grass-tree. These, when powdered and mixed with fats, would stick on the body for a long period of time.

Clothing

The only clothing worn was a fringe of narrow strips of hide, suspended back and front from a belt around the waist. This belt was made of a string of twisted possum fur, twelve to fifteen feet long. To put it on they fastened one end to a tree, and holding the other end to their waist would turn around and around until completely wound. Both sexes wore this fringe. During cold weather both sexes also wore a possum fur cloak, or a mat of kangaroo skins. When not used as a garment this latter would be used by the men as a carry-all.

The body was marked with keloids, which were produced by incising the flesh with a sharp stone, and rubbing the wounds with ashes. The keloids were made on the back of the youth when he was 17 to 20 years of age. When these healed, the

chest and later the arms would be similarly decorated. Females also wore keloids, but not to the same extent as the men. Keloids were supposed to indicate family and tribal connections.

In both sexes, the septum of the nose was pierced, and a section of kangaroo bone carried in the hole. Women were particularly fond of this ornament.

Camp Life

Habitations were a simple and rough type of shelter constructed by leaning sheets of bark against a framework of sticks.

Fire was kindled by the drill method. Two pieces of the seed stalk of the grass tree (*Xanthorrhoea*) were used for this purpose, one piece being laid on the ground and the other, sharpened to a point, was pressed against it and rapidly twirled between the hands. This soon generated enough heat to produce fire. Their food was cooked either in the ashes, or in a stone-lined pit, or oven.

Food

Food consisted of all kinds of game, birds' eggs, reptiles and insects, as well as roots and bulbs, seeds and fruits. One kind of food, however, was praised above all others: the Bogong moth.

In favourable seasons the snow would melt on the plateaux by October, and the natives would start their upward marches to secure these moths. Usually it was not until the end of December that the friendly tribes would be invited to partake of this delicacy, when from 500 to 700 aborigines were estimated to assemble on the high plains. To collect the moths, the natives, brandishing a burning bush, would enter as far as possible in any of the cracks in the rocks. The thickly congregated insects found in these crevices would be scorched, and would fall into kurrajong fibre nets or kangaroo skins which had been stretched underneath in readiness to receive them. The bogong were then unceremoniously dropped into the hot ashes of the camp fires, where the wings and legs would soon drop off, and the insect shrivel to the size of a grain of wheat. After freeing them of the ashes by winnowing, the natives would eat them by the handful. The bogong are said to be sweetish and nutty, and quite good eating.

Cannibalism was practised, and at every opportunity they would eat the flesh of their enemies, but not of members of their own tribe.

Weapons

Their weapons consisted of clubs, boomerangs, shields, stone-headed axes and three or four kinds of spears, made of reeds, seedstalks of the grass tree, box-tree and ironbark. The reed and grass tree spears were thrown with the spear-thrower, the others by hand. Boomerangs were of two kinds, the heavier fighting type, and the return boomerang. Yam-sticks for digging out roots were a convenient and necessary tool in common use. For carrying water they used bark vessels, shaped like canoes. In order to make these, a piece of bark with the ends thinned out would be placed in the hot ashes of a fire, to render the bark pliable, when it would be folded and tied at the ends.

The kurrajong nets for collecting the Bogong moths have already been mentioned. These had a very fine mesh and, for better handling, were attached laterally to two wooden sticks. The fibres used in making the nets were taken from a shrub of the *Pimelia* species, which grew plentifully along the rivers. Both the shrub and the fibre were called Kurrajong by the natives. The making of the thread necessitated

immersing the bark in water for a length of time, and subsequently, beating it soft, thus freeing the fibres to be spun. This was women's work.

Canoes

Canoes were of two kinds: those made of bark were made exactly like the water vessels, while others were veritable dug-outs, made by chopping and burning out the unwanted timber of tree trunks. Clay was used for stopping any leaks.

Stone Implements

Judging by recorded finds, their stone implements included chipped hand axes, ground-edge axes, ground-edge chisels, and hammer stones. None of the smaller conventionalized types of implements has been reported. A number of axe-sharpening stones has been found. The material used in making these tools includes metamorphosed mudstone, chert, quartzite, felspar porphyry, diorite, and chialstolite slate. The grinding stones are made of sandstone.

It is noteworthy that all the recorded specimens came from above the snow line.

Cave Paintings

Two rock shelters bearing painted designs have been found in the territory of this tribe. The designs include human and animal figures and are executed in red ochre. Because of their exposed situation the paintings are now badly faded and hard to interpret.

Language

Short vocabularies of the language spoken by these people have been published. These are listed in the bibliography at the end of this paper.

Sickness and Death

They firmly believed that all sickness was caused by an evil spirit called Jakkandibbi. It was also believed that malicious persons could throw certain small stones, called 'gibba', and cause them to enter the body of an enemy. This, of course, was done by magic, and the victim would not be aware of what befell him for some time, but would later feel discomfort and pain. These stones, however, could be removed by their own doctors or magicians, who would suck the affected part until eventually the 'gibba' were removed. This performance was coupled with violent gesticulations and strange mutterings on the part of the doctor and followed by the patient taking certain bulbs or herbs.

In the case of death great lamentations and self laceration, especially by the women took place. The body was tightly corded, with the knees drawn towards the abdomen and after being wrapped in bark was disposed of by either placing it in a hollow tree, or in a sitting position in a hole dug in the ground. In some cases a cavity or side chamber was made at the bottom of a deep hole, and the body placed in this cavity, which was then walled up with stones or logs, and the grave filled in. The idea of the side chamber was to confuse the spirit or ghost of the dead, who would not know how to get out and frighten or harm the living.

Conclusions

At this point I offer some comments and arrive at some conclusions. The aboriginal inhabitants of the highlands were of the same race, and had the same cultural traits as all the tribes round about them. The structure of the language, tribal organization, initiation ceremonies, belief in an All-Father and food habits were the same.

The differences in the names by which these people were known to Howitt and Mathews were no doubt dialectical differences as spoken by their respective informants. The same also applies to T. Mitchell who calls them Pallanganmiddah. Howitt calls the Ya-itma-thang the people who say 'Ya' for 'Yes', Mathang possibly being the same or a variant of Mittung = people. Mathews's Dyinningmiddhang is very likely: Dyinnin = yes and middhang, or the people that say 'Dyinn' for 'Yes'. Howitt calls the two sections Theddora and Kandengora. These correspond to Mathews's Dhudhuroa and Minyambutta. It is obvious that the two, the Theddora and the Dhudhuroa are the same. In each case the meaning is dhudhu or theddo, = no, and roa, or ra, shortened from whroa or whroo, = lip, i.e. the section of the people who say 'Ya' for 'Yes' are distinguished by the way they say 'No'. The same argument can be followed with the second section. Kandengora thus becomes kandengo, = no, and ra, = lip; while the meaning of Minyambuta is probably minyambu, no and ta or ra, = lip.

These tribes were inhabitants of the high plains for the same reason that other tribes were inhabitants of rain forests or deserts. This was their country, they knew every rock and water hole, where food was obtainable, and in what season. Their ancestors lived there before them, their Totemic centres were there. Even if given the choice of changing their habitat with, say, one of the coast tribes, they would not have accepted it. This applies to all aborigines, anywhere in Australia.

Owing to the fact that these particular people inhabited the mountains they had access to a class of food that was not available to other tribes except by invitation, the Bogong moth. As this moth has a place in the ecology of the high plains, a few words about it may be appropriate.

The Bogong moth, sometimes known as the plague cut worm (*Agrotis infusa*) belongs to the Noctuidae family. It inhabits the Southern Alps where it frequently appears in countless numbers. In favourable seasons the swarms may also be seen along the eastern coast line as far as Sydney, and sometimes odd moths may be collected on ships far out on the Tasman Sea. The larvae of *Agrotis infusa* is a typical cut worm, and does a great deal of damage to pastures and gardens. The fat content of the moth varies from 51% to 75% of the gross weight, depending on the time of the year and the sex of the insect. Its food value is thus considerable, and eye witnesses describe the natives as looking quite fat, and as having glossy and healthy skins when they returned from the mountains.

With the passing of the aborigines these legions of bogongs and their larvae would have presented a problem of the first magnitude, but for the tremendous increase of the crow population. These birds always have congregated on the mountain tops to feed on the swarms of moths. Their numbers, however, were kept in check by the natives, who, incidentally, ate the crows as well as the moths. The dingo and the native cat also contributed to keep the numbers of both the moths and the crows down. But now, the number of crows feeding undisturbed upon the moths is so large that, as one eye witness stated, when disturbed they rose in the air like a cloud. It has been asserted that the crows are fonder of this insect than of anything else, and that they will not touch dead or dying sheep while the Bogong moths are about.

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ECOLOGY OF THE HIGH PLAINS I

By A. B. COSTIN

Abstract

The climax vegetation of the high plains consists of subalpine woodland, sod tussock grassland, tall and short alpine herbfields, heaths, bogs and fen. Typical patterns of distribution are illustrated by reference to the Bogong High Plains area, and some comparisons are made with similar vegetation in New South Wales.

Relationships between the vegetation and habitat factors are described. These lead to hypotheses to explain the distribution of some of the communities.

Fires and grazing have produced various disclimaxes which, although satisfactory for continued extensive grazing, are inferior to the original climaxes for water yield.

Introduction

The vegetation is one of the most distinctive features of the high plains and provides the basis for defining them as ecological units. The characteristic transition from montane eucalypt forest to the more open communities of stunted snow gum, herbs and shrubs is usually complete within half a mile and often within a few yards. This change occurs near the lower level of persistent winter snow, which varies from about 4,500 to 5,000 ft depending on locality. Under special conditions of cold air drainage, pockets of high plains vegetation also occur at lower levels. The approximate distribution of the high plains vegetation thus defined is shown in Fig. 1. The total area is about 870 square miles, of which about 850 square miles occur within the altitudinal range of subalpine woodland (snow gum) and about 20 square miles, the alpine areas, occur above the tree line.

In the subalpine areas average annual precipitation varies from about 50 to more than 80 in., including snow which covers the ground continuously for at least 1 to 4 months; mean monthly temperatures reach about 50-55°F in January and fall to between 25-32°F in July. Precipitation probably exceeds 100 in. in some of the alpine areas and the snow cover persists longer; the mean temperatures for January and July are about 50 and 25°F respectively. Evaporation is probably between about 35 and 40 in. a year; the monthly values usually exceed precipitation during December, January and February, but the deficits are usually smaller than the calculated amounts of available water in the root zone of most adult plants growing on moderately deep soil (Costin 1961).

These average data are of general value for ecological work but they should be applied with caution. For example, leeward aspects receive up to twice as much snow as adjacent windward sites, and retain it up to several weeks longer. Consequently there is a wide range of micro-climates, especially on broken terrain, which is reflected in the complexity of the vegetation patterns. Other significant climatic effects not apparent from the standard data are the large number of ground frosts experienced during the snow-free months (cf. Folcy 1945) and the frequency of mists and fogs in the more southern areas.

The Vegetation and Its Distribution

Published work on the ecology of the Victorian high plains includes various local botanical surveys (e.g. Garnet 1948, Morris 1929, Tadgell 1922, Wakefield

1953, Willis 1948), a detailed study of floristic changes in grassland following protection from grazing (Carr and Turner 1958b), and broader surveys of the vegetation especially in relation to land-use (Australian Academy of Science 1957, Carr and Turner 1959a, Costin 1957a, 1957b, Patton 1953). From these accounts the following summary of ecological units has been prepared (Table 1). The nomenclature used follows Beadle and Costin (1952) and Costin (1957a).



FIG. 1—Distribution of high plains vegetation in Victoria (stippled areas).

Typical patterns of vegetation distribution, as seen on the Bogong High Plains and the adjacent Mt Bogong and Loch-Hotham-Feathertop areas, are illustrated in Fig. 2. The order of accuracy is not high, and for mapping purposes it has been necessary to map complexes rather than the individual alliances (cf. p. 331). The zonation of montane sclerophyll forest, subalpine woodland and alpine herbfield (with heath) is most simply shown on the steeper, freely drained mountains such as Bogong, Loch, Hotham and Feathertop. On the gentler sloping Bogong High Plains this pattern is complicated by the extensive development of grassland and bog (mossbeds) in the basins and valleys.

The percentage distribution of the mapping units is approximately as shown in Table 2 (after Costin 1957b). Apart from the alpine herbfield communities which are less common elsewhere, similar distribution patterns are found in other high

TABLE 1
Climax Vegetation of the High Plains and Its Distribution

Structural Form or Subform	Alliance	Distribution
Sod tussock grassland	<i>Poa caespitosa</i> - <i>Danthonia nudiflora</i>	Widespread along valleys and in basins of cold air drainage, mainly in subalpine tract. Alpine humus soils, locally gley podzols and acid marsh soils.
Tall alpine herbfield	<i>Celmisia longifolia</i> - <i>Poa caespitosa</i>	Widespread above treeline on most freely drained, relatively deep alpine humus soils.
Tall alpine herbfield	<i>Brachycome nivalis</i> - <i>Danthonia alpicola</i>	Small occurrences on steep, relatively protected alpine slopes, and rock ledges.
Short alpine herbfield	<i>Plantago muelleri</i> - <i>Montia australasica</i>	Alpine snow patch situations with at least 8 months persistent snow cover. Snow patch meadow soils, acid fen peats.
Fen	<i>Carex guadichaudiana</i>	Small occurrences in permanently wet, acid, almost level situations, influenced by mineral soil. Acid fen peats, acid marsh soils.
Valley bog	<i>Carex guadichaudiana</i> - <i>Sphagnum cristatum</i>	As for fen, but more acid, and little or no influence from mineral soil. Bog peats.
Raised bog	<i>Epacris paludosa</i> - <i>Sphagnum cristatum</i>	Locally widespread in association with acid springs and seepages, both on level and sloping sites. Bog peats.
Heath	<i>Oxylobium ellipticum</i> - <i>Podocarpus alpinus</i>	Widespread on relatively rocky, exposed and usually more snow-free situations. Lithosols, alpine humus soils.
Heath	<i>Epacris serpyllifolia</i> *	Ecotonal habitats between herbaceous vegetation and bog. Alpine humus soils, gley podzols.
Subalpine woodland	<i>Eucalyptus niphophila</i>	Subalpine climatic climax, widespread on most freely drained, relatively deep alpine humus soils, except along valleys and in basins of cold air drainage.

* Previously referred to as *Epacris serpyllifolia*-*Kunzea muelleri* alliance (Costin 1957). The name-change is desirable since *K. muelleri* is also an important component of the *Oxylobium*-*Podocarpus* heaths.

plain areas depending on whether they are predominantly plateaux like the Bogong High Plains, or steeper mountain peaks like Mt Bogong, etc. (for details see Costin 1957a).

A comparison of Table 1 with a similar table prepared for the high mountain vegetation of the mainland as a whole (Costin 1957a) reveals that the Victorian communities include all the forms and alliances other than the fjaeldmark vegetation of the Kosciusko area. Most of the association dominants listed in the Australian table are also well represented in Victoria. However, a few are not. These include *Themeda australis* Stapf., a common dominant of the sod tussock grasslands between 3,500 and 4,500 ft in the Kiandra area; the pendulous cline form of *Eucalyptus pauciflora* Sieb. ex Spreng. (Pryor 1956) in subalpine woodland also near Kiandra; and *Danthonia frigida* J. Vickery, an alpine herbfield dominant at Kosciusko. On the other hand, the Victorian herbfields contain distinctive associations of *Celmisia sericophylla* J. H. Willis as on Bogong, and of *Helipterum anthemoides* DC. as on the Crosscut Saw, whilst the subalpine woodlands of the Baw Baw Plateau

TABLE 2
Percentage Distribution of Plant Communities in the Bogong Area

Unit	Bogong High Plains*	Mt Bogong†	Mt Loch-Hotham-Feathertop (in part)‡
Subalpine woodland with heath	76	72	87
Sod tussock grassland with grassy heath	9	Tr.	Tr.
Alpine herbfield with heath	10	28	13
Groundwater vegetation (mainly bog)	5	1	Tr.

* Maps A, B, C, D of 2" = 1 mile Feathertop Sheet, Dept Lands and Survey, Victoria, 1950.

† Map B of Feathertop Sheet and Maps C and D of 2" = 1 mile Tawanga Sheet, Dept Lands and Survey, Victoria, 1950.

‡ Map C of Feathertop Sheet.

Whether grazing is continued or not, it is likely to be many years before a general condition of relative stability is achieved.

The Vegetation and Critical Habitat Factors

The main objectives of field ecology are to describe and classify the vegetation, and to ascertain its distribution in relation to critical habitat factors. The last steps are the difficult ones and in the context of the Victorian high plains involve examining the habitat factors responsible for the following vegetation changes. Such an examination helps to develop hypotheses as a guide for more critical work.

Sclerophyll Forest	—	Subalpine Woodland
Subalpine Woodland	—	Alpine Herbfield/Heath
Sod Tussock Grassland	—	Subalpine Woodland/Sclerophyll Forest
Sod Tussock Grassland	—	Alpine Herbfield
Heath	—	Sod Tussock Grassland/Alpine Herbfield
Bog/Fen	—	Non-Groundwater Vegetation

SCLEROPHYLL FOREST-SUBALPINE WOODLAND

The transition from sclerophyll forest to subalpine woodland marks the beginning of high plains conditions. Where the increase in elevation is gradual, as from Omeo towards Hotham, the transition zone is broad and forest trees of *Eucalyptus pauciflora* grade elinally into woodland trees with the characteristics of *E. niphophila* Maiden and Blakely (cf. Pryor 1956). Where the increase in elevation is sharper, as from Harrietville towards Hotham, forest trees of *E. delegatensis* R. T. Baker and *E. dalrympleana* Maiden adjoin the *E. niphophila* communities. Although sudden breaks of slope, and differences in soil depth, exposure and fire history often accentuate the forest-woodland transition, the generally significant factors appear to be winter temperature and duration of snow cover. The limited meteorological data available indicate that snow gum will replace the forest species when a mean temperature of about freezing is associated with a continuous snow cover for more than one month. Mt Buffalo, 4,370 ft near the upper limit of *E. delegatensis*, has a mean July temperature of 34.5°F. The Kosciusko Hotel in N.S.W., at 5,020 ft at the lower limit of snow gum, has a mean July temperature just below 32°. With mean temperatures of about freezing, under Australian conditions, some of the snow usually melts during the day and the snow-pack becomes 'wet'; at night it freezes again. For *E. delegatensis* Grose (1961) has shown that seedling mortality is associated with saturation of the intercellular spaces of the leaves with water from

melting snow. In laboratory trials death of water-saturated leaves occurred when the temperature was held at 33°F for about three weeks. In this regard the more glaucous leaves of snow gum may effectively resist wetting and hence enable it to survive.

SUBALPINE WOODLAND-ALPINE HERBFIELD/HEATH

At about 5,500-6,000 ft, depending on latitude and local exposure, subalpine woodland, here reduced to scrub, is replaced by alpine herbfield or heath. Such tree-line conditions have attracted world-wide attention and various explanations have been proposed. In the northern hemisphere a generally satisfactory correlation has been found between tree-lines and a mean temperature of about 50°F for the warmest month (e.g. Polunin 1960). It has also been suggested that cold environments become unsuitable for tree growth when the mean wind speed 10 metres above ground level exceeds about 6 metres per second (Braun-Blanquet 1932). In Victoria a similar correlation with mean summer temperature may also exist. At Hotham Heights, which is just below the tree-line, the mean January temperature is about 52°F. At the Kosciuszko Chalet, which is still closer to the tree-line, the temperature is about 50°. It is not clear whether tree growth is limited by the low summer temperatures themselves or by some correlated factor which has not yet been assessed.

There are, of course, several local factors which modify the actual level and position of trees in a general tree-line situation. Severe exposure to wind depresses the tree-line, as on isolated peaks such as Mt Cobbler (c. 5,340 ft) and Mt Wellington (c. 5,350 ft). By contrast, cliffs and very steep slopes are often protected by an air cushion which enables the tree-line to go higher: there are many examples in the Bluff-Mt Howitt area. Leeward slopes with more persistent snow are often treeless, although situated below the upper limit of trees, as seen on the Eskdale Spur of Mt Bogong. Conversely, relatively snow-free ridges extending beyond the general tree-line commonly support trees.

SOD TUSsock GRASSLAND-SUBALPINE WOODLAND/SCLEROPHYLL FOREST

Another type of tree-line exists on the lower slopes of broad valleys and basins. These valley tree-lines occur over a wider altitudinal range than the alpine-subalpine tree-lines just considered, from about 5,500 ft in the Bogong area down to 4,500 ft on the Bennison Plains. Descriptions of some typical topographic sequences on well drained sites assist in the analysis of this problem. The Bennison Plains, the southern valleys of the Buffalo Plateau, and the Bogong High Plains provide a series of increasing elevation.

The sequence from Mt Tamboritha (c. 5,380 ft) down to the Bennison Plains (c. 4,500 ft), a horizontal distance of about a mile, is subalpine woodland transitional to sclerophyll forest on the upper slopes, sclerophyll forest on the middle and lower slopes, with subalpine woodland fringing extensive sod tussock grasslands along the main valley. Where the slope is relatively steep, the lower subalpine woodland belt is telescoped, often to the point of elimination, so that sclerophyll forest and sod tussock grassland adjoin. It will be noted that the dominant vegetation is graded in terms of increasing cold in opposite directions, one from the middle to the top of the slope, and the other from the middle to the bottom of the slope.

On the Buffalo Plateau near the Horn, where the sequences are from about 5,500 to 5,000 ft, the sclerophyll forest belt does not occur and subalpine woodland occupies all but the lower sites where sod tussock grassland still remains.

At Pretty Valley on the Bogong High Plains, the general level is about 5,500 ft, with surrounding peaks rising to 6,000 ft. Here the zonation of tree and grassland vegetation is less regular than in the sequences at lower elevations (cf. Fig. 2). The grassland communities are far more extensive, covering not only the floor and lower slopes of the main valley but extending up the broad subsidiary valleys to the watersheds. Consequently the subalpine woodland vegetation, although generally zoned to the upper and middle slopes, has an irregular distribution especially on gentler terrain where it is often reduced to small islands of stunted trees on locally higher sites. The most extensive belts of trees occur where the upper slopes are relatively steep, as on Mt Cope and the northern section of the Rocky Valley-Pretty Valley Divide.

The common feature of these sequences is for the more cold-tolerant vegetation to occur in the lowest topographic sites. The existence of frost pockets is well known and it is common experience on the high plains that the treeless valleys are colder than the tree-covered slopes. Actual temperatures have been measured by Moore (1958) in the Currango area of New South Wales, which is similar to the Bennison Plains. Fig. 3, prepared from Moore's data, shows typical temperature patterns across the valley, as determined 2 ft 7 in. above ground level. Moore also planted out young trees of the three tree-line species at Currango, *Eucalyptus pauciflora*, *E. rubida* Deane and Maiden and *E. stellulata* Sieb. ex DC., and found that those planted below the tree-line died. Subsequent work by C. W. E. Moore (1959) showed that the nutrient status of the woodland and grassland soils is essentially similar. There is thus reasonable evidence for concluding that the absence of trees from the valleys is due to the lower temperatures caused by cold air drainage. The lower temperatures are probably most critical in spring and summer during the seedling stage.

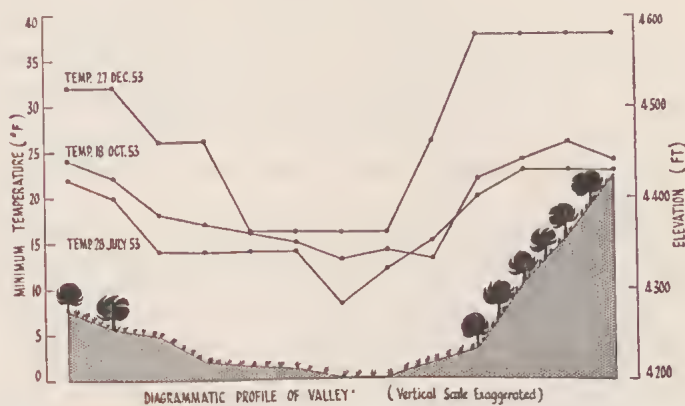


FIG. 3—Relationship between vegetation and minimum temperatures across valley.

SOD TUSsock GRASSLAND-ALPINE HERBFIELD

The main distinction between alpine herbfield and sod tussock grassland is the greater abundance of conspicuous forbs, especially *Celmisia longifolia* Cass., and to a less extent *Aciphylla glacialis*, in the herbfield communities. Floristic separation in the field is usually facilitated by spatial discontinuities: the grasslands are more common within and below the snow gum belt and the herbfields above the tree line.

The differentiating habitat factors appear to be duration of snow cover and length of the growing season; however, the responses of herbfield and grassland species to variations in these conditions have not yet been critically examined.

The above distinctions cannot always be readily made, as in Pretty Valley on the Bogong High Plains. Pretty Valley is situated at a higher comparative level than most similar valleys in Victoria and New South Wales, and this is reflected in the rather large component of alpine forbs in the grassland vegetation. In one area protected from grazing for ten years, the proportion of forbs, especially *Celmisia longifolia*, has greatly increased, and the protected community is now herbfield rather than grassland in character (Carr and Turner 1959b). Whether this represents an intermediate condition in a slow process of grassland recovery or whether it is climax herbfield remains to be seen. An important need in the study of high plains vegetation is illustrated, however, namely the determination of characteristic and differential species by which such border-line communities can be objectively and consistently classified.

HEATH-SOD TUSsock GRASSLAND/ALPINE HERBFIELD

Another difficult situation is the relationship between heath and herbaceous vegetation, especially herbfield. As indicated in Table 1, there are two main heath communities, one of relatively exposed or freely-drained rocky situations (*Oryzobium ellipticum*-*Podocarpus alpinus* alliance) and the other (*Epacris serpyllifolia* alliance) on deeper, poorly drained soils usually transitional to bog. It has also been established that exposure of bare ground in herbaceous communities facilitates invasion by shrubs which may remain for at least 50 years (Costin, Wimbush, Kerr and Gay 1959).

Apart from these situations extensive mixtures of heath and herbfield are common as a low-alpine belt just above the tree-line, as on Mt Buller and Stirling and on parts of Mt Bogong and McKay. *Hovea longifolia* (auct. non R. Br.) is usually the most important shrub, on a scale not paralleled in the more extensive alpine areas of New South Wales. Closer examination of the *Hovea*-herbfield zone frequently reveals a mosaic pattern, with *Hovea* on the slightly raised or rocky sites and herbfield in between. With increasing elevation the *Hovea* thins out leaving mainly herbfield, an effect which is clearly shown on the south-eastern slopes of Mt Buller.

The habitat differences which appear to be important are local exposure, soil depth, and duration of snow cover. These influences often vary in the same direction. The more exposed sites accumulate less snow and have shallower, stonier soils; this favours shrubs. The more protected sites accumulate more snow and have deeper, relatively stone-free soils; these conditions favour herbaceous species. With increasing elevation there is also more snow, and this likewise favours herbs.

The greater importance of low-alpine heath, especially *Hovea* communities, in Victoria than in New South Wales is related to differences in land form. The alpine areas of Victoria are mainly peaks which are relatively steep, rocky and exposed. The New South Wales areas are largely plateaux with deeper soil and generally more persistent snow.

The preference of shrubs for the more rocky and exposed situations has interesting implications as regards the probable sequence of the original plant successions. Herbs are generally regarded as an earlier stage than shrubs but in the high plains at least it is likely that shrubs (and even trees) were the pioneers. Similar conclusions have been reached on the Wasatch Plateau of the U.S.A. (Ellison 1954).

BOG/FEN-NON-GROUNDWATER VEGETATION

The main factor differentiating bog and fen communities from the rest of the vegetation is permanent wetness of ground, due either to springs or to a high water table. These wet conditions can be extended further by the expansion of the bog or fen, but this is a secondary effect. The surrounding communities are usually heaths of the *Epacris serpyllifolia* alliance or grassland characterized by the rigid-leaved ecotype of snow grass. In New South Wales the differentiation between bog and fen has been related to the acidity of the ground waters (Costin 1954). Field observations indicate similar relationships for Victorian conditions, although these have been much obscured by the vegetation changes associated with grazing.

The Vegetation and Its Utilization

In the modern world few ecological studies are complete without reference to the human factor. The effects of different types of land-use on the vegetation, and the suitability of the vegetation for different types of land-use, should be determined. On the Victorian high plains, grazing and water supply are the main considerations in this respect, and recreation is also becoming important.

Briefly, fires and grazing have caused a general opening up of the herbaceous communities with a corresponding increase in shrubs, minor herbs and bare ground; the replacement of much of the original snow gum vegetation by denser regrowth scrub; and the drying out of ground water vegetation (e.g. Costin 1957b). From the viewpoint of utilization, two distinct but overlapping stages can be recognized. The first was mainly one of selective grazing of the palatable major herbs leaving a pasture consisting more predominantly of the unpalatable snow grasses. As the palatable herbs were progressively removed a variety of shrubs and minor herbs, both native and introduced, took their place. These minor herbs provide most of the usable pasture under the second stage of grazing which exists today. In view of the susceptibility to grazing of many of the original herbs, a permanent system based on the original climax is difficult to visualize, since under extensive grazing conditions selective utilization cannot be prevented (Costin 1958). Unless sown pastures are established, therefore, high plains grazing must depend on holding secondary succession at the minor herb stage.

The value of vegetation for water supply purposes is assessed in terms of its effect on quality, regime and quantity of stream flow. Experiments in the Snowy Mountains (Costin, Wimbush and Kerr 1960) have shown that a continuous herbaceous cover at the rate of about 0.2 lb. per sq. ft oven dry weight promotes optimum infiltration and minimizes soil loss; this is the typical condition of the natural vegetation. The secondary heaths also promote good infiltration but are less effective in preventing soil loss. The widespread snow grass-minor herb communities are least effective in preventing surface run-off and soil loss; these provide ground cover at the rate of 0.1-0.02 lb. per sq. ft. On the basis of visual estimates, most of the grazed vegetation of the Victorian high plains would fall into this class.

Tree vegetation, although relatively ineffective in minimizing surface run-off and soil loss, is important for high and sustained water yield. Data from the Snowy Mountains can be directly applied to Victorian conditions. Snow gum vegetation accumulates up to 50-100% more snow water than adjacent treeless communities; moreover, the snow melt period extends up to a month longer, not being complete until after the main spring thaw. A rather open, overmature woodland also collects more snow and retains it longer than dense regrowth scrub. Furthermore, precipitation from windy rains, fog and cloud is at least 10% greater under trees than

on open ground (Costin, Gay, Wimbush and Kerr 1961; Costin and Wimbush 1961).

The hydrological role of the bog vegetation is more complex than originally believed. Because of the lag between air and subsoil temperature, the springs and ground waters entering the bog are relatively warm in winter. Provided the bog is not drained by gullies or creeks, the warmer water is spread across the whole bog and snow melt thus occurs before the snowpack on non-ground water vegetation has matured. The resultant increase in stream-flow in winter, which on the high plains is a period of low flow, is advantageous for the generation of electric power. The hydrological significance of the bogs in summer has not yet been fully assessed. It seems certain, however, that higher quality water will be produced from catchments in which the bogs are undamaged, since much of the stream flow filters through them.

These data show that a rather sparse cover of trees, underlain by a dense ground cover of herbs, with numerous bogs below springs and along the valleys, is most suitable for maximum regulated flow of high quality water. This type of vegetation has not been maintained under grazing. In fact, the most important catchment species, snow grass, is largely unpalatable, and existing grazing depends on maintaining the vegetation in a subclimax condition.

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THE VICTORIAN HIGH PLAINS—THE ENVIRONMENT AND ITS USE

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Introduction

The determination of the most suitable use for an area of land is a complex ecological problem. A satisfactory solution cannot be obtained by considering only those matters affecting the inter-relationships of plants and animals with the soil. When man becomes the dominating influence in the environment, aspects of human ecology assume importance, and social, economic and sometimes even political implications must be considered. But in spite of these complications, the major decisions about suitable and unsuitable forms of land-use for an area should be made according to scientific facts. The human factors should provide a basis for deciding only whether or not some degree of compromise is warranted under prevailing circumstances, and to what degree and for how long it can be permitted without sustaining serious and irreparable damage to the land.

Man's influence in an environment is directed generally toward obtaining the kind and level of production which he needs. Sometimes this objective is pursued without much thought about whether the productivity can be maintained. In many parts of Australia this attitude has resulted in damage to the land itself and a decline in productivity. Soil conservation aims to reverse or prevent this trend by determining those forms of land-use and management which will provide, for each kind of land, a level of productivity which can be maintained indefinitely. Basically, this is a matter of finding out how the original ecologically balanced array of plants and animals can be replaced by another managed system, in which man and the plants and animals he has introduced can survive together in the environment to provide both production and stability.

The degree of difficulty in determining desirable systems of land-use and management depends to a large extent on the nature of the original environment. For some favoured environments it is relatively easy; but for others, which even in the natural condition were in a precarious state of equilibrium, it is extremely difficult. It becomes even more difficult, if widespread deterioration is allowed to occur before some action is taken to amend a faulty system, because, instead of being faced with the modification of the original stable environment, the problem becomes one of initiating an ecological succession in an entirely new and much more difficult unstable environment, in order to achieve reclamation.

In dealing with a single landholder, modifications or changes in land use are not difficult to implement, once the landholder has been convinced of the need. However, on public land one is confronted with the conflicting opinions of different groups of people with respect to possible forms of land-use, their suitability for the area and their relative importance to the economy of the State. Consequently the problem is one of assessing the technical possibilities of the various suggested forms of land-use, their effects on the land itself, to what extent they are complementary or

conflicting, and which of them under the prevailing circumstances should be given priority in the public interest.

The Victorian high plains are public land in which different groups of people have an interest with respect to various kinds of land-use. For various reasons it is a difficult environment, which limits the possible range of techniques for providing stability under some of the forms of land-use for which some groups of people consider it to be suitable.

By direction of the Government, the Soil Conservation Authority is responsible for making decisions with respect to land-use on all areas in Victoria having an elevation of more than 4,000 ft above sea level. However, the administration of the areas still remains with the Departments in which the land is vested.

To exercise its responsibility properly, the Authority needs to know the nature of the environment, the particular characteristics which favour various kinds of use and production, and those which would prevent its safe use for certain purposes. From this information the Authority can determine the kinds of land-use to which the area can safely be put in the public interest, their relative importance, and the conditions under which such uses may be permitted.

At present there is insufficient basic information to provide categorical answers to all the problems. However, studies on the nature of the environment, and observations of changes under various kinds of use by man indicate trends and provide a warning of the need for most careful consideration in determining how these areas may be used safely in the public interest.

The Characteristics of the Environment

Detailed information about various features such as geology, geomorphology, climate, hydrology, soils, flora and fauna of the high plains, has been given by other contributors to this symposium. Collectively, these features constitute the total environment, and the information given, although more than adequate, needs to be collated and summarized, to portray a picture of the environment and its important and significant characteristics with regard to potential land-use.

The high plains, as defined for the symposium, include a number of separate areas all of which are the remnants of uplifted peneplains which have been dissected to a greater or lesser extent. The individual areas do not occur at the same elevation above sea level, but they are all higher than 4,000 ft. Because they are remnants of peneplains, the topography is rolling, and the only really steep country is that adjacent to the streams dissecting the areas and on the sides of some of the residual peaks rising above the general level of the plains.

Because of their elevation above sea level, the climate of the plains is rigorous. The precipitation is high and most of it falls as snow during the winter months. Usually the plains are completely snow-covered for several months, but there are occasions when a thin snow cover melts in the late autumn or early winter and the soil and vegetation are subject to severe frost until the area receives a new blanket of snow. The temperatures are low throughout the winter, but the most severe conditions are associated with frosts, which may occur at any time of the year. This is particularly so in areas which, due to topographic conditions, are suitable for accumulating cold air drainage.

In elevated and exposed sites, especially those with a westerly aspect, strong winds provide severe climatic conditions, both in winter, when the winds are cold, and in summer, when the winds are hot and dry. The daily range of temperature is large in summer and, during the day-time, although temperatures are not particularly

high, there is considerable incident solar energy, and the evapotranspiration, especially when there are hot dry north winds, can be considerable.

Although the climate is severe on all areas above 4,000 ft, from observations it appears that differences in elevation can ameliorate or intensify the conditions to an extent which is significant with respect to the use and management of different areas, and also to the ease or difficulty with which reclamation of damaged areas can be achieved.

Under such climatic conditions, it is to be expected that the soils and vegetation will have peculiar characteristics. The soils which have been described by Costin (1955) can be conveniently considered in three broad groups: first, the lithosols, in which there has been little profile development and the soil is really physically disintegrated parent rock with some accumulated organic matter in the surface horizon; second, the widespread alpine humus soils, which occur on the gentle well-drained slopes and show some degree of profile development; and third, a range of organo-mineral and organic soils which occur in the poorly drained and permanently wet or damp areas.

The vegetation which has been described by Costin (1957b, 1959), consists of an array of species adapted to survive under the rigorous climatic and poor soil conditions. There is a growing season of only three to four months and, because freezing temperatures can occur at night throughout the year, new seedlings can survive only under the protective cover of other vegetation. The vegetation formations are analogous to those found under similar climatic conditions in other parts of the world. However, the indigenous species are not so well adapted to survive grazing as those in other countries where close-grazing animals have been a part of the environment during the period of ecological development.

Because of their elevation, the high plains constitute the snow fields of the State and provide a natural storage of winter precipitation which is slowly released during later spring and summer. A few small areas on south-easterly aspects favour the survival of snow patches, but there is no permanent snow. The occurrence and extent of snow patches, and how long they survive, depend on the particular conditions of each season.

Although the high plains constitute only small proportions of the total area of the various catchments of which they are uppermost parts, they are important hydrologically. They are the areas of highest precipitation, and have the highest water yield per unit area of any part of the catchment. On the lower forested parts of catchments, the water yield from precipitation becomes stream flow soon after rain, and the bulk of the water yield occurs during the winter, when it is not so valuable for irrigation purposes and, once storages are full, the excess is wasted. The yield from the high plains comes later, during the spring and summer, when water is being withdrawn from storages, and it is therefore a vital component of the total water yield of the catchment.

These areas are even more important as catchments for the production of hydro-electricity, because they produce water at a high elevation.

The high plains are well watered, open, rolling country, occurring in the midst of steep, inhospitable, forested areas, and give the impression of being fertile and useful. However, this is a false impression. The soils are acid and poor, the growing season is short, the climate is severe, the vegetation is not adapted to hard grazing, and great care must be exercised in the use of the country because, once it is damaged, it is difficult to reclaim. This is because there is a restricted range of species which can be used for revegetation and because the young seedlings, even those of

native species, find it difficult to survive on open, bare ground because of the effects of frosts.

This general description of the environment applies to the high plains as a region within which there are several different kinds of country. These differences are reflected in the different soil-vegetation associations which occur in certain kinds of local climatic and topographic situations, and each of the different units requires independent consideration with respect to its possible land-use.

The different units have been described by Costin (1957a, 1957b, 1959), in varying degrees of detail, but for present purposes three major units can be considered. These are woodlands, grasslands and herbfields, and the fens and bogs of the valleys, which together constitute almost the whole of the area of the high plains in Victoria.

Land-Use on the High Plains and Its Effects

At present the high plains are used as catchments to major water supply reservoirs, catchments to hydro-electric works, for grazing, for tourist activities and for snow sports, and it has been suggested that they should also be a National Park.

Water conservation for irrigation, and also for the development of hydro-electricity, has focused attention on the importance of the high plains areas as water supply catchments. Their high elevation and the fact that they are snow-covered for part of the year makes them particularly important parts of catchments. Attention has been directed to their condition in relation to catchment efficiency, and criticism (Costin 1957a, 1958; Aust. Acad. of Sci. 1957) has been aimed not only at the effects of grazing but also at the effects of engineering works and other developments which have taken place in some parts of the high plains.

The high plains have been used for grazing for about 100 years. At first the country was used mainly for drought relief and subjected to only spasmodic grazing. However, evidence shows that during severe droughts extraordinarily large numbers of animals were crowded on to these areas and the grazing pressure was high.

At various times the areas have been grazed by horses, sheep and cattle, but for many years the only grazing has been by cattle.

The grazing value of the high plains originally was due to a variety of herbs which grow in the spaces between the snow grass tussocks. Under grazing these were quickly eaten out. When this occurred, it became the practice to burn the snow grass tussocks, to provide reasonable grazing from more palatable new growth. This had the effect of opening up the sward and left the now uninhabited bare spaces open to the frost, wind and rain. The blanket of tussock which provided insulation against frost heave was gone. The bare spaces were subject to raindrop action and to wind action. The grass tussocks were subject to blasting by soil particles blown from the inter-tussock spaces and so the grass declined and the bare spaces enlarged. Even without grazing, the revegetation of these bare areas is extremely slow and will occur only when there is sufficient top growth of the snow grass to provide an adequate protective cover against rain and wind and insulation against frost action on the soil.

The changed conditions have been more favourable to rabbits and in some places these have accentuated damage. Although grazing has caused a deterioration of the vegetative cover over large areas of the high plains, it has reached a serious state only on some of the higher and most inhospitable parts.

Excessive grazing pressure on the grassland and herbfield has to some extent

been caused by the complete loss of grazing value of some of the woodland areas as the result of fires. After fires, the snow gums regenerate by suckering and, instead of an area of grass beneath spaced individual trees, these areas become, unless grazed by sheep, an almost impenetrable scrub. Although this caused a reduction in the useful grazing area, for many years there was no reduction in stock numbers.

With the loss of vegetative cover and the increased bare space, run-off by rain-water and snow-melt was more rapid. Large areas became comparatively more arid, providing poor grazing, and cattle tended to concentrate around snow patches and in the fens and bogs during the summer. This has had serious consequences, particularly on the moss beds, which have been trampled out and desiccated. More rapid run-off has also caused some stream erosion of water courses along the valleys.

There is no doubt that the catchment characteristics have changed as the result of grazing and, in some areas, to a significant extent. However, over the whole of the high plains it is hard to estimate how significant the change has been, with respect to the efficiency of the catchment.

The construction of roads, diversion channels and dams in high country presents problems of rehabilitation of bare areas to obtain stability. Revegetation is difficult and expensive, but it is now generally recognized that it must be done.

Better access by road to these areas has encouraged more tourists, and snow sports have become an increasingly popular pastime. This has also created problems. Indiscriminate travelling with vehicles over vegetation which is sensitive to pressure and soil compaction, has left many unvegetated tracks—often straight up slopes—and these have become initial points of erosion damage. The establishment of whole villages, without proper planning for disposal of storm water or the revegetating of bare areas, has created erosion problems.

The concern about the condition of the high plains, and the criticism of the effects some forms of land-use have had in bringing about deterioration, are justified, at least with respect to some specific areas. The potential effect of the various forms of land-use is now known, because of the severe damage which has occurred in some areas and the moderate damage over broader areas which could easily deteriorate further.

The various groups of people interested in the use of the high plains for different reasons are aware of this and now agree on the need for conservation. The problem is to co-ordinate the policies of government departments and to supervise the activities of those using these areas to ensure that proper forms of land-use and the necessary reclamation works are implemented to maintain or even improve the efficiency of the area as water-supply catchments. Their importance as water-supply catchments is such that their efficiency for water production must always remain the prime consideration and all other uses should be subjugated to achieve that end.

Administration and Control of Land-Use

The high plains are Crown Lands and are mostly under the administration of the Lands Department, but the area around Mt Buller is administered by the Forests Commission and a small area around the Kiewa Works is administered by the State Electricity Commission.

For many years graziers have been given the right to graze some specified area or 'run' by the issue of an annual licence. The boundaries of the 'runs' as delineated on a map are meaningless, because they bear no relationship either to the terrain

or to the suitability of an area for grazing. So far as the grazier was concerned an annual lease was a right of entry to the area, and where his animals grazed was of no real consequence, so long as they did not wander too far away and make his task of mustering more difficult.

The number of animals put on each run was uncontrolled and consequently, as the grazing value of an area declined, there was an increase in grazing pressure on the better areas.

In 1939 the worst bushfires which had ever occurred in the State had taken their toll and, in the course of a Royal Commission, the practice of burning in mountain areas to improve grazing value was subject to severe criticism. A further Royal Commission on forest grazing revealed a need for better care of catchments and stricter control over graziers.

Control of grazing on the Bogong High Plains was instituted in 1945 when the departments concerned with soil conservation and lands, in conjunction with a committee of cattlemen, decided to reduce and control the number of animals, to ban the use of fire, and to determine dates of entry and departure of the cattle from the area in each season.

At the same time, some investigations (Carr and Turner 1959) were started to determine the effect on the vegetation if grazing were not practised.

In 1950 the Soil Conservation Authority under its new legislation established the Bogong High Plains Soil Conservation District Advisory Committee to replace the previously-constituted Committee.

Since then there has been a progressive tightening of the control and re-assessment of the grazing areas and their condition. The area around Mt Bogong has been closed to grazing since 1955, and in 1958 the area around Mt Hotham, Mt Loch and Mt Feathertop was also closed.

On Mt Buller the Forests Commission has exercised control on the numbers of cattle entering the areas each season, the fees for each run being determined on an agistment basis rather than a flat rate.

In other areas no organized control has yet been instituted; but in general the graziers have realized the need for more care and the numbers of cattle have declined.

The Authority has had inspections made of all the high plains areas to observe their condition (Costin 1957a). More recent inspections by Authority Officers indicate a reasonably satisfactory condition, except for some specific areas, and even some improvement of the country at the lower elevations.

A committee of the Australian Academy of Science made a thorough study of the condition of high mountain catchments, and in its report made several recommendations (Aust. Acad. of Sci. 1957). Of particular application to Victoria are, first, that the Soil Conservation Authority is the proper body to manage these catchments and, second, that it should be the aim to exclude all grazing from areas above 4,500 ft as soon as possible.

At this time the Government of Victoria had already directed that the Soil Conservation Authority should be responsible for decisions on land-use on areas above 4,500 ft.

In 1960 the Land-Use Committee of the Graziers' Association of Victoria investigated these areas and in its report it made several recommendations.

It recommended that the Authority should institute a form of control on the grazing of all areas above 4,000 ft elevation similar to that operating on the Bogong High Plains and that an agistment fee should be charged in addition to licence fees

to provide funds for conservation work and other projects for better management. The Committee also recommended continuing research to study the trend in catchment efficiency under grazed and ungrazed conditions and that the policy with regard to future grazing be reviewed in seven years. It also recommended the possible adoption of an agistment system to replace the present method of leasing.

Following this, the Government revised its earlier direction and made it clear that the Soil Conservation Authority was responsible for decisions on land-use for land above 4,000 ft.

This is a major task which will take some time to organize, but by the end of this year there will be control of grazing on the three major areas of high plains country and there is increasing collaboration with various authorities responsible for engineering works within these areas.

The present policy of the Authority is for multiple use of the catchment as far as this is possible. Areas at high elevations which have been seriously damaged are already closed to grazing, and investigations are being made into possible methods of reclamation using both native and introduced species, both with and without fertilizer, combined with a variety of surface protection agents.

Future Land-Use for Conservation

The major and most important use of the high plains is their capacity to store and produce water which is released to streams at an important time of the year—the late spring and summer. For this reason other forms of land-use should be permitted only if they can be practised without detriment to the areas as vital parts of catchments.

For soil and climatic reasons, agriculture is not practicable, but the high plains have some grazing value. It is true that grazing has changed the vegetation, and in some areas this has led to erosion. However, the system of grazing adopted is the most primitive which can be applied. Open range grazing without control and without any attempt to protect vulnerable areas is hardly a conclusive trial, in fact, it is amazing that, under this system which has been practised for so long, more damage has not occurred.

Throughout the State, similar problems have been faced on areas which have been very badly damaged by the systems of land-use and management used since settlement. To have condemned these areas for grazing or agricultural use on the basis of what had happened under primitive methods of land-use and management, without trying improved systems, would have been a completely negative and wrong approach.

To condemn grazing on all high plains, without trying improved systems, is also a negative approach which is not warranted at present, except in certain critical areas which occur more frequently at the higher elevations.

Although the condition of the high plains is not perfect, no authority in Victoria has yet considered that erosion is seriously damaging its installations. The threat is real, but there is still time to determine whether adequate control and an improved approach to grazing management can achieve a satisfactory condition.

Although attention has been focused on the high plains, some of the lower forested parts of catchments are not in good condition and at present constitute a greater threat than erosion on the high plains. This is particularly so in the Glenmaggie catchment.

There are several improvements in grazing management which might be investigated. The control of cattle numbers and the dates of entry and departure

in accordance with seasonal conditions have already led to an improvement on part of the Bogong High Plains. Systems of deferred grazing with the cattle under the control of a ranger throughout the whole season will not only provide seasons of rest for the country, but will also prevent stock from damaging vulnerable parts of the area. An agistment system instead of the present system of leasing runs will be fairer, easier to administer and will enable better control to be made of the stocking rate in relation to the carrying capacity of the country. The provision of watering places away from bogs has already proved successful in the Mt Buller area.

These, and other improvements will be tried before grazing is completely condemned.

Forestry on the high plains is probably not impossible, but highly unlikely as a form of land-use. Because of exposure, establishment would be difficult even for suitable species, and the growth rate would be slow. The establishment of trees in suitable locations, if it is possible, may be an advantage to catchment efficiency, because of the effect of trees in trapping and holding snow and delaying the thaw. So far, no investigations have been made of likely exotic tree species for this purpose.

Snow sports and tourist activities are becoming increasingly popular and the establishment of villages at high elevations can present problems. But this is a form of land-use which will continue and develop, and positive conservation works and the education of the people participating will be required to prevent damage.

Engineering works on high plains are always troublesome, but all constructing authorities are now aware of the need for care and for positive conservation works to reclaim exposed areas. However, it is important that these bodies should seek advice on conservation and reclamation at the planning stage and not after the works have been completed.

Finally, there is the consideration that these areas should become National Parks. Mt Buffalo is a National Park, but it is not truly representative of the high elevation country. Unfortunately areas of high elevation country, such as Mt Hotham and Mt Feathertop, which may have been suitable once, are certainly not in a suitable condition for a National Park at present.

There is not yet sufficient basic information to provide categorical answers to the land-use problems of the area.

Little is known about the possibility of introduced species and their possible effect in making grazing a less hazardous form of land-use. Although there has been hydrological research (Costin 1959, 1960) there is yet no answer to the hydrological significance of the moss beds and the bogs in the total catchment efficiency. Although it is known to be important, little has been done about increasing snow retention by artificial means. There is much to learn about techniques for the reclamation of areas denuded of vegetation whether by grazing, by engineering works, or by the tramping of people.

From observation it seems possible to have multiple use of the high plains where the elevation is below 5,000 ft, and such an objective can be pursued without great risk. For land above 5,000 ft it seems unlikely that any forms of land-use, other than water production, will be found to be safe or desirable, and the objective should be to maintain and, if possible, improve its condition as catchments.

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THE GEOLOGY OF THE KIEWA AREA

By F. C. BEAVIS, BSc PhD

Abstract

Upper Ordovician sediments were folded and metamorphosed with migmatization on the cores of the main anticlines, during the Benambran Orogeny. Later intrusion of granodiorites took place in the post tectonic intrusive phase of the Bowring Orogeny, and of quartz diorites and lamprophyres in the same phase of the Tabberabberan Orogeny. The early stages of the Kosciusco Uplift were marked by the extrusion of basic lavas.

The dominant fold structure is the Kiewa Anticline, a broad, relatively simple structure, the axis of which has a gentle northerly plunge, and the W. limb of which is sheared through on the West Kiewa Thrust. This thrust, the main fault of the area, forms here, the W. boundary of the metamorphic complex. The structure is dominated by faults and joints, the pattern of which is related to the three Palaeozoic orogenies known to have affected the region. After the Benambran folding, no further folding occurred, with the exception of a fault warp in the Tertiary. Deformation during the post Benambran Palaeozoic orogenies was expressed by fracturing.

The stream pattern, as well as the overall topographic form of the terrain, has been strongly influenced by the faulting, and in particular by the Tertiary fault-warping.

Introduction

The Kiewa area includes the headwaters of the Kiewa, Bundarra, and Cobungra R., all of which have their sources on the Bogong High Plains. The terrain is extremely rugged, comprising some of the highest parts of the Victorian Alps. Elevation ranges between 1,100 ft at Mt Beauty township, and 6,509 ft on the summit of Mt Bogong. With the exception of the Bogong High Plains, dissection is deep, with the streams actively eroding steep, gorge-like valleys. Weathering of the rocks is advanced, and in general, exposures of fresh rock are restricted to the beds of streams.

The field work, which consisted of regional and very detailed mapping of an area of 300 square miles, together with a large amount of diamond drilling, provided the basic data for the research into the age and relationships of, particularly, the igneous and metamorphic rocks of this sector of the metamorphic complex of NE. Victoria. Petrological studies were essential for this aspect of the project and while earlier workers had studied the petrology of the complex as a whole, very little such work had been attempted for this area.

The most detailed part of the project was the structural research, an aspect of the geology of the Kiewa area which had previously not been examined. Patterns of folding, faulting, jointing and dyke intrusion have been studied. The field work emphasized the importance of structure in the physiographic development of the area, while civil engineering design and construction for the Kiewa Hydroelectric Project emphasized the significance, economically, of structure. Both of these aspects were investigated, the latter in more detail than can be considered in this paper.

This paper is based on part of a thesis for the degree of Doctor of Philosophy in the University of Melbourne. The author desires to express appreciation for the guidance of Professor E. S. Hills. Drs C. M. Tattam, O. P. Singleton, and R. J. W. McLaughlin discussed various aspects with the author, while Dr Tattam read

the manuscript. The field work was carried out mainly in the period 1947-1957 when the author was employed by the Geological Survey of Victoria, and the State Electricity Commission of Victoria. It is desired to express appreciation for the inspiration and opportunities provided by Dr D. E. Thomas and Mr G. Paterson. Messrs A. Rufenacht, R. G. Chapman, E. L. Richard, H. H. C. Williams, T. D. Eaton and D. Gibson made possible many aspects of the work. L. F. Huelin and L. J. Clarke served as field assistants. To the author's parents, his wife, and the late Dr W. J. Harris sincere thanks are due for the encouragement given at all times. Assistance to the cost of publication by the University of Melbourne is gratefully acknowledged.

Previous Literature

R. A. F. Murray carried out the first geological survey in the Kiewa area; his main interest was the distribution of the auriferous sub-basaltic gravels, but he claimed recognition of the transition of the Ordovician sediments to metamorphic rocks in the West Kiewa valley. In 1886 von Lendenfeld and Stirling separately explored Mt Bogong from which they recorded material interpreted by them as Pleistocene moraine.

J. W. Gregory (1902) examined the metamorphic boundary at a number of localities, and concluded that this boundary was always faulted. This led to Gregory ascribing a pre-Cambrian age to the metamorphic rocks, a conclusion which Tattam (1929) was unable to substantiate. Tattam's work on the metamorphic rocks showed for the first time that the metamorphism was essentially thermal.

Between 1930 and 1940, J. P. L. Kenny, J. G. Easton, and M. A. Condon carried out preliminary geological investigations for the Kiewa Hydroelectric Project. This work has been described in a number of small reports, both published and unpublished. V. M. Cottle, continuing the work for the Project published a report on the Ruined Castle basalts in 1947.

P. W. Crohn (1949) made a study of the geology of the Omeo district, and extended his rapid surveys to include the E. part of the Kiewa area. Crohn's work included a detailed study of the petrology, as well as a critical review of the physiography of the region. Studies of Tertiary thrusting and of the mylonites of the Kiewa area have been published by the present author (Beavis 1960, 1961).

Geology

AGE AND FIELD RELATIONSHIPS

Rocks ranging in age from Upper Ordovician to Recent are exposed in the Kiewa area. The youngest of the Palaeozoic rocks are epi-Middle Devonian in age, while the oldest of the Cainozoic rocks are of Oligocene age. The intervening period apparently was one of non-deposition and erosion. The present distribution of the Cainozoic rocks is very restricted, and it is probable that this was the case even at the time of their deposition and extrusion.

Determination of the age and relationships of the Palaeozoic rocks required examination of sections outside the Kiewa area. Often these factors were determined, of necessity, purely on petrological evidence. Within the area mapped the faulted nature of many of the boundaries necessitated correlation on this basis also. The area is a small sector of the metamorphic complex of NE. Victoria and SE. New South Wales: consideration of local stratigraphic relationships had to be based on the complex as a whole.

Palaeozoic sedimentation occurred in what is known as the Tasman Geosyncline,

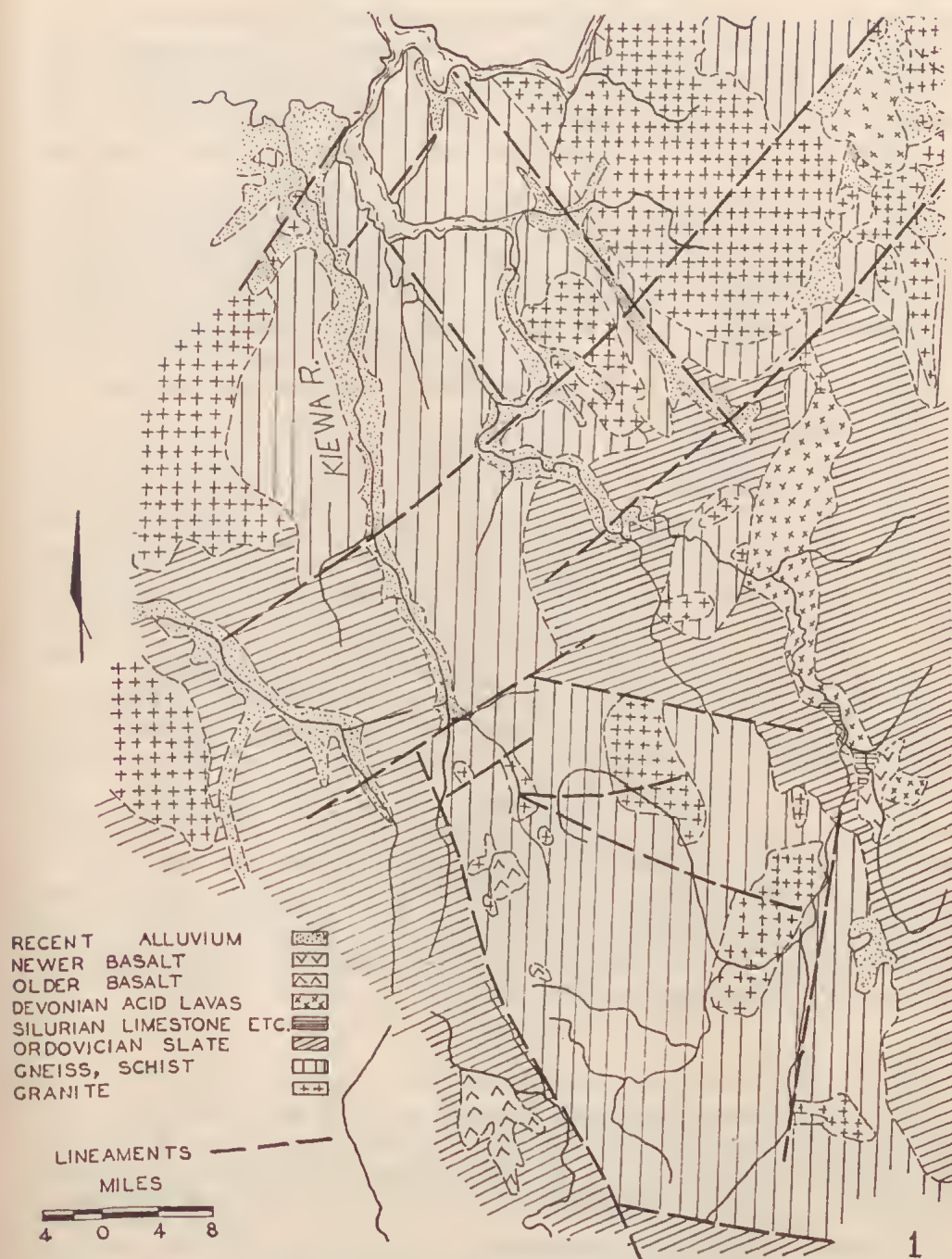


FIG. 1—Regional Geological Map of part of Metamorphic Complex, NE. Victoria.

and the Palaeozoic stratigraphy of the Kiewa area is to be regarded as part of the sequence of events constituting the history of this geosyncline. It is noteworthy that even the late Tertiary diastrophisms in Victoria were concentrated in this belt, and it is apparent that the mobility of the belt has remained. Moreover, early in the Palaeozoic, parts of the geosyncline ceased to be basins of deposition, and it seems preferable therefore to refer to this belt as the East Australian Mobile Belt (Hills 1956).

A series of orogenies described by David (Browne 1950) have been considered responsible for the folding of the sediments of the East Australian Mobile Belt. These orogenies have been local, e.g. the epi-Ordovician Benambran Orogeny, during which the Upper Ordovician sediments of Kiewa were folded, was restricted to E. Victoria and E. New South Wales. Near Orange, N.S.W., there is no evidence of this orogeny, while in Central Victoria, the passage from the Upper Ordovician to Silurian is conformable. The epi-Silurian Bowning Orogeny was similarly restricted, since in Central Victoria, the Silurian sediments pass conformably up into the Lower Devonian.

The work of Tattam (1929), Edwards and Easton (1937), and Crohn (1949), as well as that of earlier geologists, particularly Howitt, has built up a general picture of the metamorphic complex. The oldest rocks, the Ordovician sediments, range from Darriwilian to Upper Ordovician (Thomas 1949). In some areas, these rocks have been metamorphosed about granites. Apart from this local metamorphism, there is a belt over 100 miles long, and at least 30 miles wide, which has undergone regional metamorphism. There is a marked constriction in this belt near Tawonga, due to faulting, and there is evidence that elsewhere many of the boundaries of the metamorphic belt are faulted (Fig. 1). Much of the E. boundary of the metamorphic belt, however is a normal transition from unaltered Ordovician sediments.

The regional metamorphism is to be dated with the epi-Ordovician Benambran Orogeny. The migmatites ('permecation gneiss') are also this age, and represent the ultimate products of the metamorphism. These migmatites form the core of the complex.

Intrusions of granitic rocks are widespread. These are of two ages: the older are the grey granites and granodiorites, tentatively correlated with the post tectonic phase of the Bowning Orogeny; the younger pink granites and quartz diorites, which at Pine Mountain and Mt Mittimaitite intrude the grey granites, are correlated tentatively with the post tectonic phase of the epi-Middle Devonian Tabberabberan Orogeny. Associated with these younger intrusions was a swarm of basic to intermediate lamprophyric dykes. With rare exceptions, the intrusions were post tectonic, only one case of syntectonic intrusion having been recorded.

PALAEOZOIC ROCKS

UPPER ORDOVICIAN SEDIMENTS: THE HOTHAM SLATES

Slates, greywackes, and orthoquartzites occur on the W. flank of the Kiewa area, extending W. from the West Kiewa valley, and typically developed at Mt Hotham. The lithology tends to be monotonous, with slates predominating in the Hotham area, but greywackes become more important further W. Conglomerates and limestones are absent, and the only igneous material is seen in the coarser constituents of the greywacke, which have been derived from granitic rocks. The slates are grey in colour, are sometimes phyllitic, and apparently are unfossiliferous.

T. S. Hall (1908) recorded *Dicellograptus* from Myrtleford, and Harris and Thomas (1941) the following graptolites from Edi:

*Climacograptus bicornis**C. bicornis* var. *peltifer**Diplograptus* spp.*Dichranograptus nicholsoni* var. *parvanguis**Dicellograptus* sp.

From Wombat Cr., Ferguson (1889) recorded:

*Dicellograptus elegans**Climacograptus bicornis*,

while the present author obtained fragments of *Dicellograptus* and *Diplograptus* from the Rose R. These assemblages are characteristic of an horizon low in the Upper Ordovician. Despite careful search, no fossils were found in the slates at Kiewa, and it has been concluded that the sediments in this area are unfossiliferous.

TABLE 1
Stratigraphic Succession in the Kiewa Area

Age	Formation	Tectonic Episode
Recent	Newcr Alluvials	Kosciuskoan Uplift
Pleistocene-	Tawonga Gravels	
Pliocene	Unconformity	
? Miocene-	Bogong Volcanics	
Oligocene (Older Volcanics)	Unconformity	Tabberabberan Orogeny
epi-Middle Devonian	Big Hill Quartz Diorite	
epi-Silurian	Kiewa Granodiorites East Kiewa and Niggerheads Granodiorite Pretty Valley Gneissic Granodiorite	
epi-Ordovician	High Plains Gneiss Mt Nelse Schist	Benambran Orogeny
Upper Ordovician	Hotham Slates	

A detailed traverse along the Kiewa-Eildon power transmission line from the Rose R. to Bright showed no major structural or stratigraphic discontinuity, and this, with the evidence of the typical lithology, is the basis for ascribing an Upper Ordovician age to the slates of the Hotham-West Kiewa belt.

THE BENAMBRAN OROGENY: HIGH PLAINS GNEISS AND MT NELSE SCHIST

Gregory (1902) claimed a pre-Cambrian age for the schists and gneisses, and considered that these were faulted against the Ordovician sediments. Crohn (1949)

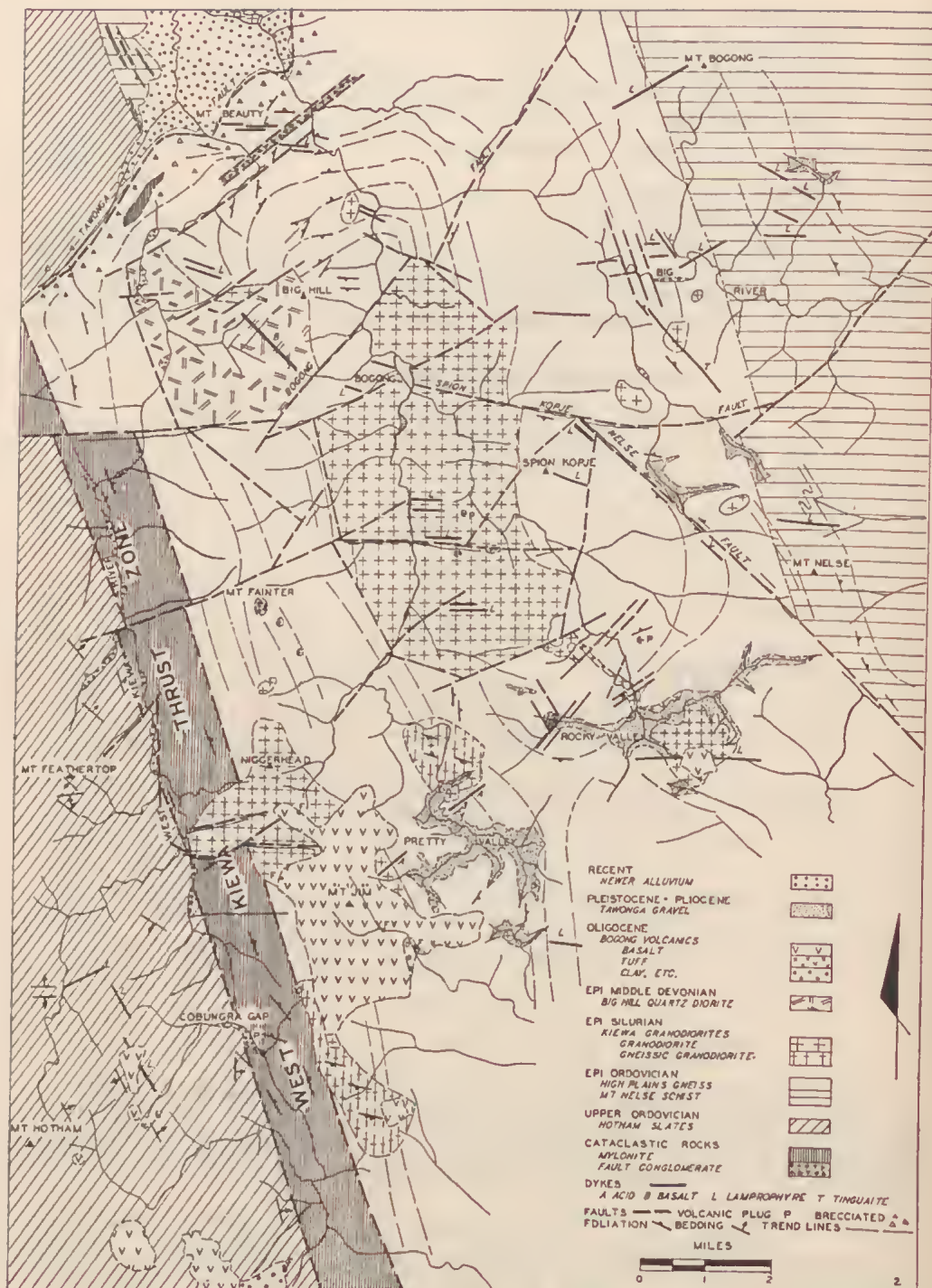


FIG. 2—Geological Map of the Kiewa Area.

considered that two belts of schist occurred: one, a very narrow belt along the W. margin of the area; the other, a wide belt extending easterly from the High Plains to the Mitta Mitta valley. The present author has examined the sediment-schist relationships in both belts, but with particular attention to the W. belt. At Cobungra Gap, one of Gregory's described sections, the chloritic slates are shattered, and pass into low grade schists, having very restricted development. At the Gap, the rocks are brecciated which was doubtless Gregory's evidence for faulting. The low grade schists pass into mylonites which form virtually the whole of the West Kiewa 'schist' belt (Beavis 1961). This mylonite forms the crush zone of the West Kiewa Thrust. Gregory's conclusion that the boundary of the metamorphic rocks at Cobungra Gap is faulted is thus confirmed, although Gregory's picture of the faulting was somewhat different from the present interpretation. Crohn's idea of a normal transition cannot be substantiated in this section.

The Mt Nelse Schists comprise medium to high grade metamorphic rocks which are exposed between Mt Nelse and Mt Bogong. To the W. they are transitional to permeation gneiss, and they are bounded in the N. and in the S. by faults. To the E. there is little doubt of the transition of these schists from the Upper Ordovician sediments; Gregory's dating of the schists as pre-Cambrian was therefore erroneous.

Zones of varying grades of schist were recognized in the field, but actual mapping of the zones was almost impossible. The two main zones in the Mt Nelse area are those of knotted schist, and of biotite sillimanite schist. The zonal boundaries are parallel to the boundary of the gneissic belt. The Mt Nelse Schists are transitional to the W. to the High Plains Gneiss.

In his definition of the High Plains Gneiss, Crohn (op. cit.) included at least the highest grade schists as well as the Pretty Valley Gneissic Granodiorite. These are excluded from the presently defined unit. The High Plains Gneiss is a migmatitic rock, called in this paper 'permeation gneiss', which occupies a belt some 6 miles wide in the N. sector of the area, and up to 14 miles wide in the S. This unit forms the core of the metamorphic complex. The High Plains Gneiss is transitional from the schists, although in part faulted against them. Foliation is continuous through the transition. In the W., the High Plains Gneiss is bounded by the West Kiewa Thrust.

Within the Kiewa area itself, there is no direct evidence of the age of the schists and permeation gneiss. Hills and Thomas (1953) noted that in Eastern Victoria, a tectonic episode occurred at a time that can be dated as post Upper Ordovician and pre Lower Devonian, since the gneiss is overlain with strong angular unconformity by the Lower Devonian Snowy River Porphyries. These authors regard the orogeny—the Benambran—as being of Lower Silurian age, relating it to changes in the conditions of sedimentation in the Central Victorian trough.

Crohn (op. cit.) claimed that the Wombat Cr. Formation succeeded the Upper Ordovician sediments without any break, the boundary between the two being marked by the incoming of conglomerates and limestones. The author has not been able to confirm Crohn's claim. Faulting marks the boundary in part at least, whilst in places there is some evidence of angular unconformity. The age of the Wombat Creek Formation has for some years been in dispute. Ferguson (1889) first described fossils from the formation, and suggested an Upper Silurian age. Chapman (1912, 1917, 1920) referred a number of localities to the Middle Devonian, and the remainder to Yeringian, then regarded as Upper Silurian. J. Talent (1960) considers the age to be pre-Middle to Middle Silurian. The Tambo Formation, of probable Middle Devonian age, rests on the schists with an angular unconformity. This formation has been metamorphosed by the granite porphyry of Mt Sisters.

David (Browne 1950) postulated the formation of a geanticline, consisting of metamorphic rocks, in the East Australian Mobile Belt during the Benambran Orogeny, dated as epi-Ordovician. The evidence presented above tends to confirm this concept, and would date the metamorphism and migmatization as Benambran. The igneous activity (migmatization) is to be regarded as syntectonic.

THE BOWNING OROGENY: THE KIEWA GRANODIORITES

Intrusive into the Ordovician sediments, the schists, and the permeation gneiss are two suites of granitic rocks. The older of these are the grey granodiorites and gneissic granodiorite. David (Browne *op. cit.*) dated the granites and diorites of the Yackandandah district, as well as some of the Kiewa intrusives, with the Bowning Orogeny of epi Silurian age. Crohn (*op. cit.*) recognized two suites of intrusives in the Omeo-Kiewa area, and whilst he was not specific, it would appear that he referred the grey granodiorites of Kiewa to the older suite.

There is no direct evidence at Kiewa which would justify certain correlation of the granodiorites with the Bowning Orogeny: they are certainly younger than the Benambran permeation gneiss, and older than the ? Tabberabberan quartz diorite. Talent (1960) has found definite evidence of Bowning intrusion in NE. Victoria in the Berridale Granite, but has found no evidence of Benambran intrusion.

At Kiewa, two phases of Bowning intrusion are recognized. The first was the syntectonic intrusion of the Pretty Valley gneissic granodiorite, the second, the normal post-tectonic intrusion of normal granodiorites. The Pretty Valley Gneissic Granodiorite is exposed in two adjoining areas on the Bogong High Plains between Pretty Valley and the Bundarra R.; it is possible that continuity may exist at shallow depth. The gneissic granodiorite has the composition of a normal granodiorite, but it is strongly foliated, and has a discontinuous banding. The gneissic granodiorite is intrusive into the permeation gneiss on which a thermal metamorphism has been imposed. The margins of the gneissic granodiorite transgress the foliation of the permeation gneiss, but the long axes of the somewhat elliptical shaped masses of the gneissic granodiorite are parallel to the structural trend of the country rock. This is of interest since the foliation of the gneissic granodiorite is almost normal to this trend.

Included in the gneissic granodiorite are xenoliths and roof pendants of biotite sillimanite schist and metaquartzite. These are frequently elliptical in plan, with the long axes parallel to the foliation of the host rock. Some are banded with pegmatic material. The rocks constituting the xenoliths are typical of the highest grades of schist, the nearest present exposures of which are at Mt Nelse, some miles to the N. None the less, some lenses of these rocks are to be found in the mylonite belt of the West Kiewa Thrust, and it is apparent that the schists may have been present at Pretty Valley at the time of intrusion of the gneissic granodiorite.

The contact between the gneissic granodiorite and the permeation gneiss was observed both at the surface and in the No. 1 Head Race Tunnel. The tunnel section showed reaction between the two rocks, as well as the localized metamorphism and the concentration of acid dykes at the contact. The more southerly mass intrudes not only the permeation gneiss but also the West Kiewa mylonite, in which a very narrow contact aureole has been developed. This mass is elongated along the margin of the Thrust, and some control of the intrusion by the Thrust zone may have been exerted.

Two main masses of normal granodiorite occur: the Niggerheads and the East Kiewa. The former, with normal intrusive contacts against the permeation gneiss and the West Kiewa mylonite, is faulted against the Upper Ordovician sediments in

the West Kiewa Valley. The Niggerheads mass has a crudely rectangular form, with the long axis parallel to the regional trend of the country rock. This is also true of the East Kiewa Granodiorite, exposed in the East Kiewa Valley; most of the contact of this mass, however, is faulted. Where the contacts are normal, as on the flanks of Spion Kopje, and at Langford's Gap, a contact aureole some 500 ft wide has been developed in the permeation gneiss.

Numerous small masses of granodiorite and granodiorite aplite occur throughout the area. One of these, a richly garnetiferous granodiorite, is intrusive into the Pretty Valley Gneissic Granodiorite. Recrystallized granodiorite aplites outcrop on Timm's Lookout, on the spur running down from the Lookout to Big R.-Cairne Cr., and as an inlier in the Newer Alluvials at Tawonga South. Localized recrystallization has been observed in the East Kiewa Granodiorite. The most extensive area is at Bogong township, where the recrystallized rock forms bold, fresh, outcrops in contrast to the deeply weathered normal granodiorite.

All of the granodiorites show strong petrographic similarities with those of Yackandandah and elsewhere in the region which David (1950) dates with the Bowning Orogeny. The close of this orogeny at Kiewa was marked by intense faulting, the first movement on the Tawonga Fault probably being of this age.

THE TABBERABBERAN OROGENY: THE BIG HILL QUARTZ DIORITE

The Big Hill Quartz Diorite is intrusive into permeation gneiss and granodiorite. At the contact with the latter, a complex of alkaline syenitic rocks occurs. All of these are deeply weathered, and exposures were too restricted for detailed study. Where the quartz diorite is exposed at higher altitudes, melanocratic schlieren are abundant. These are absent at lower altitudes, suggesting that the higher exposures are close to the original roof of the pluton.

The S., W., SE., and part of the N. boundaries are faulted. There is some evidence, discussed in a later section, that the quartz diorite was originally in direct contact with the East Kiewa Granodiorite, with displacement occurring along the Bogong Fault. In the Lower West Kiewa Tunnel the contact of the quartz diorite with permeation gneiss was exposed. This contact is very sharp, with only a 10 ft zone of thermal metamorphism recognizable in the gneiss.

Lamprophyre dykes have intruded all of the Palaeozoic rocks in the Kiewa area, including the quartz diorite. These dykes are much younger than the pegmatite dykes, many of which are cut by lamprophyres. The relationship between the lamprophyres and the Tertiary rocks is seen in Rocky Valley where a hornblende lamprophyre intrudes the granodiorite, and is overlain by the basal flow of limburgite at Basalt Hill. Although the survey of Crohn covered a wider area than that of the writer, no evidence was found to substantiate the former's claim that the lamprophyres are restricted to the margins of the main gneissic belts. Several thousands of these dykes have been mapped, and their distribution appears to be uniform. There is a close relationship between the crush zones of faults and the dykes, which frequently occur on the walls of the crush zones. The pattern of distribution is consistent in the tendency for the dykes to occur in groups of 3 to 5, closely spaced, but with some hundreds of feet between groups.

CAINOZOIC ROCKS

THE BOGONG VOLCANICS

The Bogong Volcanics are defined as a formation comprising basalts, with lesser phonolites, and doleritic and alkaline dykes; associated with the lavas are gravels,

sands, clays, tuffs, and brown coals, the sediments often fossiliferous. The Formation is restricted to the Bogong High Plains and the higher parts of the adjacent mountain areas. Excluding the pyroclastics, two main types of sediment have been recognized. Lacustrine sediments occur below and intercalated with the basalts of the High Plains: fluviatile sediments are exclusively sub-basaltic and are restricted to Mt Fainter and the Hotham area.

Beneath the basalt of Mt Fainter, some 30 ft of river gravels are exposed. At Hotham Heights, excavations at White's Mine have exposed a considerable thickness of these gravels together with associated fluvio-lacustrine sediments, some of which contain poorly preserved plant remains. A typical section, now largely obscured, has been described by Kenny (1937):

	Ft		Ft
Surface soil	3	Ligneous clay and sand .. .	20
Sands	10	Gravels	20-30
Ligneous clays	15	Hotham Slates	
Gravel	30		

By contrast, the sub-basaltic sediments of the High Plains are purely lacustrine, and are richly fossiliferous. The section on the Bundarra R., first described by Murray (1878), and later by Crohn (1949) is now known in more detail:

	Ft		Ft
Basalt		Micaceous sandy clays, in part	
Sandy clays and sand	4	tuffaceous, with stumps .. .	14
Brown coal	1	Mottled grey and brown clays	14
Red and grey fossiliferous shale	1	Gneiss	
Grey, poorly fossiliferous shale	2		

The best known sequence of inter-basaltic sediments is at West Dyke, where close drilling was carried out:

	Ft		Ft
Basalt		Brown Coal	1
Tuffaceous clays (? soil) .. .	4	Grey fossiliferous silty clay ..	19
Yellow silty clay	5	Basalt	
Grey fossiliferous shale .. .	1		

At 'The Lake', landslides have exposed thick, massive sandstones, with leaf impressions, and thin, richly fossiliferous shales. Elsewhere about the basalts of Mt Jim, outcrops of fossiliferous clays have been observed. Fossils recorded from these sediments include:

Drypteris dargoensis
Taeniopteris tenuissimae striata
Phyllocladus sp.
Agathis sp.
Araucarias sp.
 Insectae indet.

The brown coal is comparable in composition and moisture content to the oldest of the Latrobe Valley coals, which may be as old as Eocene. The Kiewa flora suggests an Oligocene to Miocene age (O. Selling, personal communication), but precise age determination is not possible.

Basalts, limburgites, and alkaline differentiates occur in two relatively restricted areas: on the Bogong High Plains, between Rocky Valley and the West Kiewa R., and in the Mt Hotham-Upper Ovens area. The most important occurrences on the High Plains are Basalt Hill, Ruined Castle, and Mt Jim, with a small outlier on Mt Fainter, and plugs on Junction Spur, Roper's Lookout, Rocky Cr., and Cobungra

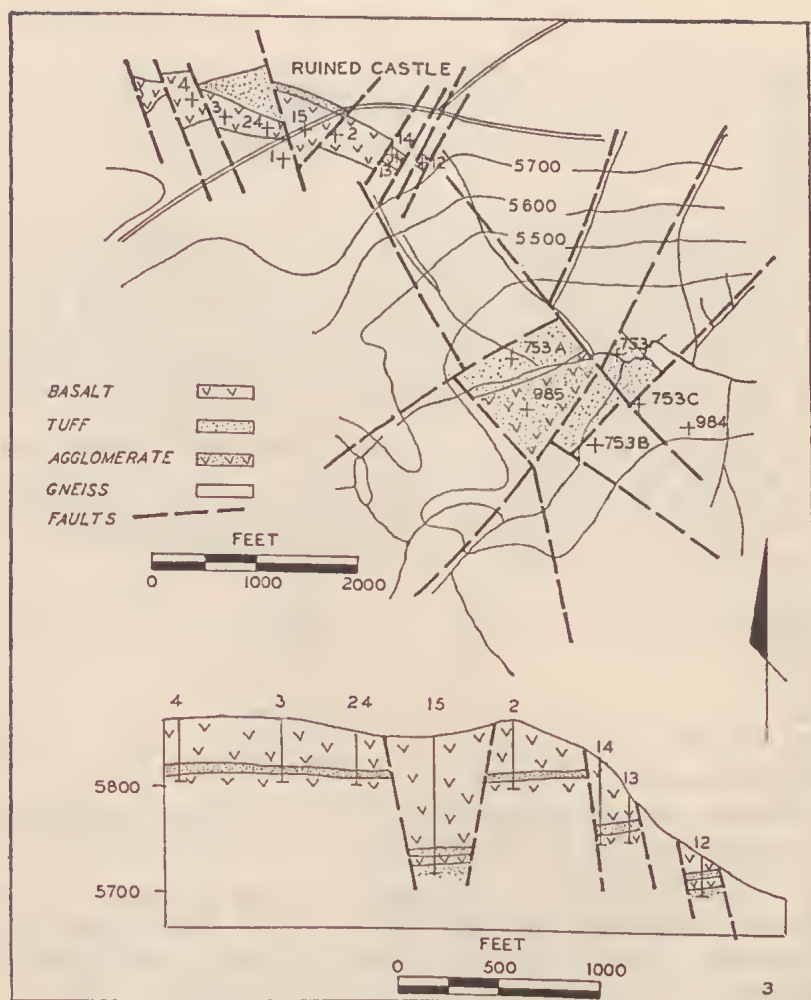


FIG. 3—Basalts at Ruined Castle and Rocky Cr.

Gap. The occurrences at Hotham include Mt Hotham, Mt Loch, Mt Higginbottom, and the phonolite of Mt Smythe. The lavas form some of the higher, but not the highest, parts of the terrain.

Three flows may be recognized at Basalt Hill. The basal flow is a limburgite, with thickness ranging between 30 and 180 ft. The middle flow, olivine basalt, is 30 to 90 ft thick, while the upper flow, also olivine basalt, forms a veneer only 15 ft in thickness. No sub- or inter-basaltic sediments occur, but scoriaceous material was observed at the base of the lower flow.

At Ruined Castle, the extent of the basalts and tuffs is greater than that indicated by Cottle (1947), and moreover, the relationships are considerably more complex. Faulting has been extensive, and it is due to this deformation that the columns show gross irregularities of plunge. Tuff, at least 50 ft thick, is faulted against the N. edge of the basalt (Fig. 3). Basalts and tuffs alternate:

	Ft		Ft
Basalt	51-110	Tuff	10
Tuff	12	Basalt	1
Basalt	9	Tuff	8
Tuff	5	Basalt	2
Basalt	6	Tuff	50
Tuff	7	Basalt	5
Basalt	6		

Cottle's suggestion that the basalts and tuffs occupy an old river valley cannot be confirmed with the evidence available. Nowhere has a bore penetrated to bedrock. Variations in the level of the base of the uppermost flow, as well as the rectilinear boundaries are due to faulting. The adjacent Rocky Cr. basalt-tuff-agglomerate association is also faulted. The bore evidence alone suggests that this association marks a point of eruption, but the more than 300 ft thickness of pyroclastics in bore 753A can also be explained in part by downthrow along mapped faults. In view of the nature of the materials, there seems little doubt that this is a locus of eruption, modified by faulting.

The 7 flows of olivine basalt and limburgite at Mt Jim constitute the largest outlier of volcanic rocks in the Kiewa area. Together with intercalated sediments, the total thickness is over 500 ft:

	Ft		Ft
Basalt	70	Basalt	30
Sands, coal, etc.	30	Sandstone	6
Basalt	52	Basalt	33
Tuffs	2	Clay, coal, tuff	36
Basalt	35	Limburgite	30
Clay, coal, tuff	94	Clay, sand, coal	80
Basalt	49	Gneiss	
Clay and coal	5		

Both Dibbin's Lookout (limburgite) and Young's Lookout (olivine basalt) are outliers from the main Mt Jim series. There is no evidence that Dibbin's Lookout is a plug (cf. Edwards 1938).

Hills (1939) citing Condon's description of Roper's Lookout as a denuded cone, considered a possibly young age for some at least of the basalts. Very close field examination of this feature, with Condon's field notes available, failed to verify this interpretation. Roper's Lookout is rather to be regarded as a plug.

Although olivine basalts predominate in the Hotham area, this area differs from the High Plains in the occurrence of phonolites, the most important of which is Mt Smythe. Nowhere in the area has a direct field relationship between the basalts and the phonolites been observed.

Dykes of dolerite, olivine basalt, and tinguaita occur sporadically. These are tentatively correlated with the Bogong Volcanics on petrological grounds, although the dolerites show some affinities to the lamprophyres, as do some of the basalt dykes. The petrological evidence alone is frequently inconclusive.

The age of the olivine basalts and associated lavas is almost certainly Lower Cainozoic, because of their intimate association with plant beds of this age. The basalts are therefore to be correlated with the Older Volcanic rocks of Victoria. As stated above, Hills tentatively suggested a possibly younger age for part at least of the Bogong Volcanics, while Thomas (1949) referred to Mt Jim as a possible locus of eruption of late Cainozoic age. In fact, Mt Jim is a remnant of the formerly more extensive uppermost flow of the outlier. The columnar jointing is regular, and this, together with the complete absence of pyroclastics suggests that Thomas's idea was not valid.

THE KOSCIUSCO UPLIFT: LATE CAINOZOIC ALLUVIALS

Uplift of the Kiewa area during movement on the Tawonga Fault is regarded as a phase of the more general Kosciusco Uplift, dated by David as late Pliocene, but as even younger by Jaeger and Browne (1958). Later discussion in this paper will develop the writer's idea that movement began in the early Cainozoic, and persisted to the Pleistocene.

Two formations of late Cainozoic alluvium have been recognized in the area: the Older Alluvials (Tawonga Gravel) and the Newer Alluvials. The Tawonga Gravel comprises medium to coarse gravels, typically developed near Tawonga, where the thickness may exceed 200 ft, and where they are conformably overlain by the Newer Alluvials. They occur in the mature valleys of the High Plains, also, where thickness is rarely greater than 10 ft. These sediments are typically fluvial, and show no evidence of a lacustrine origin (cf. Carr and Costin 1955). The Tawonga Gravel was involved in movement on the Tawonga and Sassafras Creek Faults.

The Newer Alluvials are of two types: peat, up to 5 ft thick, in the sphagnum bogs of the High Plains, and sands and gravels, currently being deposited on the valley floors. These sediments do not appear to have been involved in fault movements, which apparently ceased in the Pleistocene.

Pleistocene glaciation in the area was first discussed by Stirling (1886), and later by Crohn (1949) and by Carr and Costin (1955). It is clear (Beavis 1959) that no evidence of such glaciation is to be found in either the late Cainozoic sediments or in the physiographic features.

Petrology

Petrological studies by Tattam (1929) in Victoria, and in New South Wales by Joplin (1942, 1944, 1947) showed the essentially thermal nature of the metamorphism in the metamorphic complex. The petrological work described in this paper adds little that is new to our knowledge of the metamorphic rocks, with the exception of the recognition of the importance of shearing stress on a local scale in the late and post metamorphic periods. The study of the igneous rocks is more important since these have not been described previously; moreover, the petrology was frequently the sole basis for the correlation of these rocks with others outside the area, the age of which is known.

UPPER ORDOVICIAN SEDIMENTS: THE HOTIHAM SLATES

On the immediate W. flank of the Kiewa area the sediments of this age are dominantly pelitic, but further W., near Bright, subgreywackes, greywackes, and quartzites become more important. The chemical analyses of these rocks (Table 2) demonstrate that the sediments are rich in alumina and potash, and in fact, that the alumina content of the slate is abnormally high. Tattam (op. cit.) recorded a slate from Mt Wagra with 24% alumina, so that excessively aluminous slates may not be uncommon in this area. The sedimentary assemblage is characteristic of the late stages of geosynclinal deposition: particularly important in this regard is the pronounced development of greywackes (Pettijohn 1957).

In the hand specimen, the slates appear to be uniform, but in thin section fine internal stratification is well marked. The main constituents are fine quartz, rare feldspar, sericite and chlorite. Recrystallization of sericite to muscovite and of chlorite to biotite was observed. The greywackes occur in thin beds and, unlike the slates, lack any internal stratification; graded bedding is characteristic. These sediments

are composed of angular to subangular grains of quartz, oligoclase, rare orthoclase and microcline, all of which show authigenic sericite on the grain boundaries. The coarse constituents are set in a matrix of finer quartz, and sericite and chlorite, with occasionally some secondary calcite. Detrital almandine, tourmaline, magnetite, and more rarely zircon and andalusite occur as heavy accessories. More arenaceous types, transitional to quartzites, are composed of subangular grains of quartz, with feldspar very rare, in a quartzose matrix, which contains a little sericite and chlorite. The quartzites are composed almost exclusively of subangular grains of quartz, on which are secondary outgrowths of quartz. Feldspar is very rare, and only occasionally was sericite observed.

TABLE 2
Analyses of Upper Ordovician Sediments

	1	2	3
SiO ₂	50.64	62.95	77.68
Al ₂ O ₃	24.55	18.35	11.69
Fe ₂ O ₃	2.32	4.28	1.68
FeO	4.44	0.56	1.91
TiO ₂	0.83	0.65	0.10
CaO	0.25	0.98	0.43
MgO	2.61	1.65	1.52
Na ₂ O	0.30	0.42	0.90
K ₂ O	5.95	3.85	2.59
MnO	0.03	—	0.02
P ₂ O ₅	0.05	0.15	—
H ₂ O—	0.32	0.50	0.26
H ₂ O+	6.65	6.34	2.29
	98.94	100.68	101.07

Analyses: V. Biskupsky

	4	5
Quartz	32.3	63.1
Oligoclase	15.9	10.7
Orthoclase	3.5	tr.
Mica	0.9	2.1
Matrix	46.0	22.5
Accessories	1.4	1.6
	100.0	100.0

1. Slate, Mt Hotham; 2. Greywacke, Bright;
3. Quartz sandstone, Mt Feathertop; 4. Same specimen as 2; 5. Same specimen as 3.

MT NELSE SCHISTS

Within the area studied low grade schists were observed only as thin lenses in the mylonites of the West Kiewa Thrust Zone. The schists of the Mt Nelse-Mt Bogong belt are high grade types, in which a distinct zoning may be recognized. The low grade schists of West Kiewa are strongly foliated, and are composed of quartz and very fine flakes of light brown mica. A little calcic feldspar and epidote may also be present. The lowest grade schists of the main belt are those exposed on T Spur, Mt Bogong. These are fine textured, strongly foliated rocks, with locally, a tendency to banding. Porphyroblasts up to 5 mm in diameter stand out as

ellipsoidal knots on the weather surface, and develop a strong lineation. In thin section the knots are seen to be zoned, with an outer zone of fine pinite, and a core of coarser pinite, muscovite, anhedral to subhedral biotite, and minute crystals of cordierite and quartz. The matrix of the rock is composed of fine flakes of biotite and needles of quartz. Associated with each knot is a 'tail' of quartz which imparts the apparent banding to the schist. The 'tails' may contain some feldspar and cordierite. The foliation of the matrix curves around the knots, while quartz rich 'tails' terminate abruptly against them. This schist has the mineral assemblage of the hornblende hornfels facies of Fyfe, Turner and Verhoogen (1958).

The fine pinitic material was examined by X-ray diffraction (Table 3). The data obtained, and particularly the fineness of the 10A line, suggest that shearing stress was not responsible for the retrograde development of pinite from cordierite, confirming Tattam's conclusion that the pinitization was a retrograde thermal feature. No doubt exists that the pinite was derived from cordierite, both from the evidence in thin section, and that of the X-ray study. Walker (1950) showed that the position of the (060) reflection can be used to determine whether the mica is dioctohedral or trioctohedral. In this pinite the (060) reflection occurs at 1.56 kx indicating a trioctohedral type, derived from cordierite.

TABLE 3
X-ray Powder Pattern: Pinite

I (est.)	8	3	5	1	10	6	4	2	3	1	2	$\frac{1}{2}$
d (kx)	10.02	5.04	4.52	3.73	3.52	3.27	2.51	2.49	1.78	1.67	1.56	1.48

The knotted schist from Mt Nelse-Timm's Lookout is a higher grade type than that of Mt Bogong. The knots are composed of poikiloblastic aggregates of pinite; the inclusions are cordierite, flakes of muscovite, strained quartz, and strongly pleochroic green brown biotite. Surrounding the knots is a rim of dark brown biotite, sometimes partly replaced by sillimanite and sometimes bleached, the transition from brown to colourless biotite sometimes occurring within the length of a single crystal. Almandine is frequently intimately associated with the biotite, and tourmaline is relatively common. The matrix of this schist is composed of quartz, frequently strained, and enclosing needles of sillimanite. Biotite and deformed muscovite also occur in the matrix, together with andesine and partly pinitized cordierite. There is some evidence in the strained quartz that this rock has been subjected to post recrystallization shear, probably associated with movements on the nearby Nelse and Spion Kopje Faults.

Interbedded with the knotted schists at Mt Nelse are strongly foliated, fine to medium textured quartz hornblende almandine schists. These are composed of quartz, strongly poikiloblastic cordierite, almandine, oligoclase, and abundant green, lime rich amphibole. Magnetite and tourmaline are secondary accessories.

Both on Mt Bogong and Mt Nelse the knotted schists pass up into higher grade quartz feldspar sillimanite cordierite almandine biotite schist. In one specimen from T Spur, traces of the knots may be seen, but the pinite largely appears to have been recrystallized to muscovite. Quartz enclosing sillimanite shows strain. The cordierite is strongly poikiloblastic. The biotite is green brown, strongly pleochroic, and contains numerous minute inclusions of black iron ore. Andesine and almandine occur in accessory proportions only. Some secondary tourmaline is always present. At Aertex Hut on the same spur, sillimanite increases in importance.

In Big R., the schist is very coarse textured (crystals up to 3.5 mm) and strongly foliated. Quartz, oligoclase-andesine, dark brown, almost opaque, biotite, sillimanite and muscovite are the essential constituents, with almandine occurring sporadically.

These schists have mineral assemblages of the hornblende hornfels facies, with features suggesting transition to the almandine amphibolite facies. The quartzofeldspathic assemblage seen in the quartz amphibole almandine schist does not appear to have been described previously, but the intimate field association with the knotted schists indicates that it is an assemblage of the same facies. It is to be noted that the knotted schists of Mt Bogong do not show the transitional aspects of those of Mt Nelse.

TABLE 4
Chemical Analyses of Schists

	1	2	3	4	5	6
SiO ₂	75.45	66.71	56.90	99.35	72.49	52.70
Al ₂ O ₃	13.76	16.48	21.85	0.65	14.78	24.10
Fe ₂ O ₃	1.21	0.45	0.65	0.05	0.88	1.68
FeO	2.09	4.10	3.98	—	2.20	4.63
TiO ₂	0.51	0.70	0.71	0.01	0.51	0.52
CaO	0.24	0.54	0.78	—	6.82	0.27
MgO	1.40	2.41	2.09	—	1.11	3.46
Na ₂ O	0.45	0.58	0.64	—	0.45	0.51
K ₂ O	3.47	4.22	5.93	—	tr.	6.84
MnO	0.03	0.07	0.04	—	0.05	0.04
P ₂ O ₅	0.08	0.10	0.09	—	0.15	nd
H ₂ O—	0.12	0.35	0.67	0.03	0.21	0.26
H ₂ O+	2.01	3.05	5.15	0.02	0.69	4.85
	100.82	99.76	99.48	100.11	100.34	99.86

1. Low-grade quartz biotite schist, Cobungra Gap; 2. Quartz biotite almandine schist, West Kiewa; 3. Knotted schist, T Spur, Mt Bogong; 4. Quartz schist, Mt Nelse North; 5. Quartz amphibole almandine schist, Mt Nelse; 6. Pinite from knotted schist (Tattam 1929).

Analyses: V. Biskupsky

The analyses illustrate the wide variations in the schists. The nature of the amphibole in the quartz amphibole almandine schist is seen in the high lime content of this rock. This rock, and a xenolith from the permeation gneiss are the only two examples of lime rich sediments in the area. The importance of additions of potash during the pinitization of the cordierite of the knotted schist is to be noted in analysis 3. The alumina content of analysis 3 also suggests derivation from pelitic sediments, while the rocks of analyses 1, 2, and 5 appear to have been derived from greywackes.

Where the schists have been intruded by later granodiorites, the most important feature of the resulting contact metamorphism has been the development of sillimanite at the expense of biotite. Near Mt Nelse, the knotted schists, where they are in contact with granodiorite have been completely recrystallized, with the development of crystals of pink, strongly pleochroic andalusite, up to 5 in. long.

PERMEATION GNEISS: HIGH PLAINS GNEISS

The permeation gneiss is markedly heterogeneous both in composition and texture. Foliation and banding, with some notable exceptions, are well developed,

and almost certainly have been inherited from the original sediments. In the field the permeation gneiss is characterized by both banding, and the frequent occurrence of biotite rich lenses and pegmatitic quartz-potash feldspar nodules, up to 2 ft long. Macrobands of nonfoliated gneiss occur. These are probably representatives of Tattam's granulite, and may represent the quartzitic beds of the original sediments. Xenoliths occur in the permeation gneiss. These are of two types, one gneissic, and transitional in composition between high grade schists and the gneiss itself, the other type is hornfelsic, and includes a wide range of petrographic types.

Sillimanite and cordierite are typical constituents of the permeation gneiss, although the latter is frequently pinitized. Quartz, biotite, and feldspar are the other essential constituents. Almandine occurs commonly, but always in accessory proportions. The quartz usually encloses needles of sillimanite, and may show myrmekitic intergrowth with alkali feldspar near the crystal boundaries. Orthoclase, orthoclase perthite, and more rarely microcline are usually in excess of andesine, although in some cases the andesine predominates. Biotite is of two types: one dark brown, almost opaque, with inclusions of zircon around which pleochroic halos have been formed; the other is a light brown variety, lacking inclusions, and strongly pleochroic. This clearly indicates two generations of biotite. Another important distinction is that while the dark biotite is replaced to some degree by sillimanite, this replacement is lacking from the lighter variety. The sillimanite occurs as rods in the quartz, and as felted masses after biotite. Although cordierite is invariably present, pinitization has occurred, with subsequent recrystallization of the pinite to muscovite. Some of the white mica observed in the gneiss is bleached biotite. Apatite, zircon, sphene and rutile are common accessories.

The nonfoliated gneiss has a greatly reduced content of biotite, sillimanite, and cordierite. The texture is coarse, granoblastic, and the essential constituents are quartz, orthoclase, orthoclase microperthite, andesine, and sometimes white mica. Biotite and sillimanite are to be regarded as accessories only. Almandine also occurs as an accessory.

The leucocratic lenses in the gneiss have a pegmatitic texture and may represent segregations, or later additions, of granitic magma. Crystals of quartz, and feldspar, showing pegmatitic intergrowth are up to 5 mm in diameter. The feldspar is orthoclase, orthoclase microperthite, or commonly, microcline. Andesine is rare, and muscovite is sporadic. Almost invariably these nodules are surrounded by a zone of biotite rich material. The biotite flakes have a preferred orientation parallel to the margins of the nodules, and may indicate reprecipitation after reconstitution of the original rock. The biotite rich melanocratic lenses are composed essentially of biotite, sillimanite, and rare quartz and muscovite. Sillimanite has almost completely replaced the biotite.

Xenoliths in the permeation gneiss are most common near Mt Cope. The commonest type shows a moderately strong foliation due to parallelism of biotite flakes. The biotite is light brown in colour, and pleochroic. Quartz, orthoclase, and andesine are abundant, while almandine may be abundant or present only in minor amounts. Another type, with granoblastic texture, is composed of quartz, almandine, and biotite. One group, which is fairly common, has only a weak foliation, but with blastoporphyritic texture well developed. Green, strongly pleochroic amphibole occurs in a fine matrix of quartz, andesine, orthoclase, and almandine. A similar textural type has large porphyroblasts of diopside in a quartz-feldspar matrix. This assemblage is of considerable interest, since it is a typical calcareous assemblage of the pyroxene hornfels facies, and is the other of the two indications of lime rich sediments previously noted.

The permeation gneiss has been thermally metamorphosed where it has been intruded by later granodiorites. Typical of the metamorphism is the development of porphyroblasts of mauve cordierite. This is clearly seen at Langford's Gap in Rocky Valley. In some cases, as on Spion Kopje, the calcic cores of the plagioclase have been replaced by clinozoisite. Almandine is also characteristic of the contact zones, while the quartz is spongy with inclusions.

TABLE 5
Analyses of Permeation Gneiss

	1	2
SiO ₂	70.49	72.65
Al ₂ O ₃	17.13	16.81
Fe ₂ O ₃	1.04	1.07
FeO	1.56	2.08
TiO ₂	0.36	0.40
CaO	1.40	0.80
MgO	1.31	1.29
Na ₂ O	1.60	1.50
K ₂ O	2.80	2.50
MnO	0.04	0.05
P ₂ O ₅	0.03	0.04
H ₂ O—	0.13	0.13
H ₂ O+	1.30	1.35
	99.79	100.67

Analyses: V. Biskupsky

	3	4	5	6	7	8	9	10	11	12
Quartz	69.3	13.4	31.6	59.0	62.0	53.1	0.7	80.9	83.1	78.8
Orthoclase	tr.	—	—	1.6	1.3	6.3	—	2.7	1.3	3.2
Microperthite	4.3	40.0	1.0	—	—	—	—	—	—	—
Microcline	—	41.5	—	—	—	—	—	—	—	—
Plagioclase	6.2	—	61.5	18.8	4.0	3.9	—	1.0	1.6	1.0
Biotite	13.5	—	3.2	16.0	13.3	28.2	86.7	7.6	13.5	13.1
Muscovite	—	5.1	2.4	1.0	4.5	5.7	10.2	—	—	—
Cordierite	1.7	—	tr.	0.3	1.1	tr.	—	0.1	—	—
Almandine	tr.	—	—	—	tr.	—	—	7.1	—	—
Sillimanite	4.5	—	tr.	1.7	11.3	1.9	2.1	—	—	0.4
Accessories	0.5	tr.	0.3	1.6	2.5	0.9	0.3	0.6	0.5	3.5

1. Permeation gneiss, Rocky Valley; 2. Leucocratic lens, Rocky Valley; 3. Permeation gneiss, Rocky Valley; 4. Leucocratic lens, Rocky Valley; 5. Permeation gneiss, No. 4 Power Station; 6. Permeation gneiss, No. 4 Head Race Tunnel; 7. Permeation gneiss, Clover Dam; 8. Permeation gneiss, Clover Dam; 9. Biotite rich lens, Fall's Cr.; 10-12. Xenoliths in gneiss, Mt Cope.

INTRUSIVES: PRETTY VALLEY GNEISSIC GRANODIORITE

With the essential composition of a granodiorite, the Pretty Valley gneissic granodiorite has a well developed foliation, and discontinuous, somewhat lenticular banding. The rock mass is relatively homogeneous, with very little variation in composition or texture. Quartz occurs as anhedral pools up to 2 mm in diameter, sometimes with corroded margins. In a few specimens, orthoclase was in excess of oligoclase-andesine, but overall, the ratio of orthoclase to plagioclase is 1:3, with the rock of the more southerly mass particularly showing a much reduced orthoclase

content. The plagioclase is frequently idiomorphic, and may be enclosed in quartz; sometimes the felspar occurs as groups of crystals crowded between large pools of quartz. In one specimen from Pretty Valley dam site, the plagioclase occurs as anhedral crystals 4 mm in diameter, the cores are sericitized, and are surrounded by oligoclase, with shadow zoning and twinning. Micrographic intergrowths of quartz and felspar were noted occasionally. The biotite is light brown in colour, and has been locally chloritized. Replacement of biotite by sillimanite was noted, but this is rare. Almandine is sometimes associated with the biotite. Cordierite, zircon, apatite, and sphene are accessories. Secondary chalcopyrite and clinozoisite are present along joints.

The large rafts of schist which occur at Pretty Valley have been partially granitized. Myrmekitic and micrographic intergrowths of quartz and felspar are common. Orthoclase and plagioclase are present in equal proportions; the felspars are frequently poikilitic enclosing minute crystals of biotite and quartz. The biotite is generally bleached, and is partly replaced by sillimanite. Fine needles of sillimanite also occur in the quartz. Almandine and cordierite are essential constituents, the latter often pinitized.

A series of acid dykes is intimately associated with the gneissic granodiorite. Many of these are quartz-potash felspar pegmatites; a few are aplites. The aplites have a sugary texture, with relatively large (0.8 mm) crystals of quartz and orthoclase common, and andesine, less common. There is a tendency for the biotite to be segregated about the grain boundaries of the plagioclase. At Pretty Valley North, almandine is an essential constituent.

Granite dykes are also relatively common. These have a medium (2 mm) hypidiomorphic texture. Orthoclase and microcline are in excess of sodic oligoclase. Quartz is abundant, and is euhedral. Muscovite, poikilitic, and partly resorbed, is in excess of biotite. Cordierite, apatite and zircon are accessory.

INTRUSIVES: NIGGERHEADS AND EAST KIEWA GRANODIORITES

The Niggerheads granodiorite is a medium textured rock, composed of anhedral crystals of quartz, andesine and orthoclase, with the former dominant, and green brown biotite. The biotite is commonly replaced by clinozoisite and magnetite, while plagioclase, with sericitized cores, is often enclosed in the biotite. Apatite and zircon are accessory. A fine grained phase is present on the E. margin of the mass. Crystal size is rarely greater than 0.7 mm. The composition is the same as that of the coarser rock, but the andesine is poikilitic, and cordierite is an important accessory.

While the Niggerheads granodiorite is reasonably uniform, wide variations in both texture and composition occur in the East Kiewa granodiorite. Most of the variations appear to be the result of shear and metasomatism (Baker 1950). At Bogong Village the granodiorite has a medium (1.0-1.3 mm) even texture, with quartz, orthoclase, microcline, andesine and biotite the main constituents. Further N., green-brown, strongly pleochroic hornblende becomes important, and at the N. margin, is in excess of biotite. It is not unusual for the hornblende to have a core of light brown biotite. In the N. the biotite is replaced by magnetite in a number of localities.

At Windy Gap near Rocky Valley, the quartz is subhedral to euhedral, in contrast to the generally anhedral form elsewhere. Here also, muscovite is an essential constituent. At No. 1 Power Station a fine, very dark variety occurs, with biotite the main constituent. In Rocky Valley, between Howman's Gap and Bogong

TABLE 6
Analyses of Gneissic Granodiorite

	1		2	3	4
SiO ₂	64.36	Quartz	31.3	35.5	33.3
Al ₂ O ₃	20.41	Orthoclase	18.7	15.9	9.8
Fe ₂ O ₃	1.65	Plagioclase	27.2	35.2	35.3
FeO	2.96	Biotite	19.6	11.8	20.5
TiO ₂	0.41	Muscovite	tr.	—	tr.
CaO	4.63	Cordierite	tr.	1.0	0.6
MgO	1.48	Sillimanite	tr.	tr.	—
Na ₂ O	1.55	Accessories	3.2	0.6	0.6
K ₂ O	2.11				
MnO	0.03				
P ₂ O ₅	0.03				
H ₂ O—	0.23				
H ₂ O+	0.70				
	100.55				

1. Gneissic granodiorite, Pretty Valley Dam Site (V. Biskupsky); 2. Gneissic granodiorite, Pretty Valley Dam Site; 3. Gneissic granodiorite, Pretty Valley; 4. Gneissic granodiorite, Cobungra.

Village, relatively large zircons are present; almandine after biotite, and sillimanite after quartz are also found in the granodiorite.

Varying amounts of shear, metasomatism, and recrystallization have been observed in this granodiorite. These are seen also in a number of smaller granodiorite stocks throughout the area. At Langford's Gap and at Rocky Valley Dam the plagioclase has been almost completely sericitized, with partial recrystallization of the sericite to muscovite. On Frying Pan Spur, and the Spion Kopje fall of Rocky Valley, similar features, together with some recrystallization of the quartz were noted.

Shearing is localized on well defined zones. Granulation is a reflection of minor shear, but the ultimate product is a mylonite (Beavis 1961). The principal effects of metasomatism have been bleaching, the introduction of secondary quartz, calcite sulphides, the replacement of ferromagnesians by clinozoisite, and the saussuritization of the feldspars. Metasomatism has been most effective in and adjacent to shear zones. At Howman Dam Site, a typical rock has been observed. The biotite is bleached, and partly replaced by clinozoisite. The poikilitic feldspars are saussuritized, and secondary quartz and pyrite are present. It is clear that at least two periods of metasomatism have occurred: the older, a quartz-sulphide metasomatism is probably to be dated with the final stages of Palaeozoic intrusion, and the younger, a calcite metasomatism, is of Tertiary (volcanic) age.

INTRUSIVES: BIG HILL QUARTZ DIORITE

The deep dissection of the quartz diorite of Big Hill has permitted an examination of the rock over a vertical distance of some 3,000 ft. The only distinction between the high and low level exposures, however, is the absence from the latter of the melanocratic schlieren which are typical of the high levels.

The most outstanding feature of the quartz diorite is the abundance of euhedral, frequently twinned crystals of green brown hornblende. Quartz occurs as anhedral pools. Plagioclase (An 40–35) is the commonest constituent, occurring as large

TABLE 7
Analyses of Granodiorites

	1	2
SiO ₂	65.00	65.50
Al ₂ O ₃	19.33	14.75
Fe ₂ O ₃	1.83	3.13
FeO	3.08	2.20
TiO ₂	0.04	0.34
MnO	0.08	0.07
P ₂ O ₅	0.04	0.13
CaO	3.28	3.28
MgO	1.60	1.06
Na ₂ O	1.35	3.80
K ₂ O	2.45	3.12
H ₂ O—	0.12	0.12
H ₂ O+	0.90	0.83
	100.16	99.33

Analyses: V. Biskupsky

	3	4	5	6	7	8	9
Quartz	38.4	25.5	29.8	32.5	41.9	24.7	26.1
Orthoclase	25.9	19.9	6.1	14.5	3.2	13.9	26.1
Plagioclase	21.6	43.3	49.1	37.4	26.5	38.5	31.2
Biotite	10.1	9.3	9.3	16.3	20.9	20.5	16.1
Muscovite	—	—	—	—	tr.	—	—
Hornblende	—	1.3	—	0.1	—	—	4.3
Epidote	tr.	—	1.1	tr.	3.2	tr.	tr.
Cordierite	—	—	—	—	1.1	—	—
Accessories	4.0	0.4	1.1	2.4	tr.	2.4	1.2

1. Granodiorite, McKay Cr.; 2. Granodiorite, No. 3 Tunnel; 3. Pink granodiorite, No. 3 Tunnel; 4. Grey granodiorite, No. 3 Tunnel (Baker 1950); 5. Metasomatized granodiorite, Howman's Gap; 6. Pink-green granodiorite, No. 3 Tunnel (Baker op. cit.); 7. Granodiorite, No. 1 Power Station; 8. Granodiorite, Niggerheads; 9. Granodiorite, Bogong.

(3 mm) subhedral crystals, rarely zoned. Flakes of light brown biotite occur, all of which, in all sections examined, has been partially resorbed, and in a few cases has been replaced by magnetite. Ilmenite and leucoxene after ilmenite, zircon, apatite, magnetite and pyrite are accessory.

The schlieren of the high level exposures are of two types: one has a fine texture, with maximum crystal size 0.2 mm, the other is coarser, with crystals 0.5 mm in diameter. Both have much the same composition. Quartz is present in minor amounts. Orthoclase is rare, but frequently, poikilitic andesine, enclosing needles and flakes of hornblende and biotite, may constitute a greater proportion of the rock than in the normal quartz diorite. Biotite and hornblende, usually anhedral, are very common. Clinzoisite is secondary, and forms the core to some of the strongly zoned plagioclase.

At the contact between the quartz diorite and granodiorite a complex of relatively alkaline rocks occurs. Unfortunately the extremely deep weathering, and the consequent poor exposures did not permit field relationships to be studied. One type in the complex is a granite. Coarse textured, with crystal size 5 mm, this rock is

composed of anhedral quartz, microcline, microcline-micropertthite and orthoclase in excess of oligoclase, and frequently poikilitic biotite. Another type is a quartz syenite. The texture is medium, with microcline, microcline-micropertthite, and orthoclase in excess of sodic oligoclase. Quartz, biotite and muscovite are minor constituents.

TABLE 8
Analyses of Quartz Diorites

	1		2	3	4	5	6
SiO ₂	62.54	Quartz	14.6	3.8	1.0	39.6	13.1
Al ₂ O ₃	18.65	Orthoclase	6.9	1.3	3.2	tr.	1.5
Fe ₂ O ₃	2.06	Microcline	—	—	—	40.8	28.9
FeO	3.32	Micropertthite	—	—	—	—	51.8
TiO ₂	0.47	Plagioclase	46.4	64.5	67.6	7.7	0.3
MnO	0.05	Biotite	14.6	2.8	0.4	11.0	1.1
P ₂ O ₅	0.02	Muscovite	—	—	—	tr.	1.6
CaO	4.80	Hornblende	15.9	27.7	25.2	—	—
MgO	2.29	Epidote	tr.	—	—	—	1.0
Na ₂ O	2.50	Accessories	1.5	0.4	2.6	0.9	0.6
K ₂ O	2.22						
H ₂ O—	0.14						
H ₂ O+	0.47						
	99.53						

1. Quartz diorite, saddle between Big Hill and Bald Hill (V. Biskupsky); 2. Quartz diorite, Big Hill; 3. Fine textured schlieren, Big Hill; 4. Coarse textured schlieren, Big Hill; 5. Granite, Big Hill; 6. Quartz syenite, Big Hill.

LAMPROPHYRE DYKES

The rocks of this group are chiefly lamprophyres, but also to be considered here are felspar porphyrites, monchiquites and some of the basaltic dykes which show affinities to the lamprophyres. Baker (1950) described those rocks of this group which were exposed in the No. 3 Tunnel as spessartites, camptospessartites, augite lamprophyres, camptonites and monchiquites. Thin sections of 110 dykes have been examined, and Baker's nomenclature has been retained, with the recognition of the additional felspar porphyrite and microdiorite. Some types approach odinite and kersantite in composition; variation was considerable, however, and recognition of these types did not appear to be warranted. The intense metasomatism of many of the dykes prevented certain identification. Hornblende is the most important constituent of the dykes, being an essential in 70 of the specimens studied.

The spessartites have a panidiomorphic texture, and are strongly porphyritic. The phenocrysts, invariably euhedral, are up to 1.5 mm long, and are hornblende and andesine. The groundmass is composed of hornblende and andesine, with microcrystalline texture. Magnetite may be abundant. The felspar phenocrysts are frequently zoned, with the cores highly calcic. At No. 4 Power Station, one spessartite dyke has a chilled margin. The texture of the marginal rock is cryptocrystalline to microcrystalline, with some rare skeletal crystals of hornblende, and abundant magnetite. Xenocrysts of quartz have been partly absorbed by the dyke rock.

In the camptospessartites euhedral phenocrysts up to 2 mm long occur in a microcrystalline matrix. Most of this type examined showed advanced metasomatism; the phenocrysts of augite have been almost completely replaced by

clinozoisite, but the brown hornblende phenocrysts are less affected. The feldspar, originally labradorite, have been saussuritized. Any andesine present is restricted to the groundmass.

A dyke on Timm's Lookout is one of the few on the area which may be referred with certainty to the camptonites. The texture is hypidiomorphic microporphyratic, with microphenocrysts 0.6 mm long, of euhedral zoned augites, the cores titaniferous, and the outer zone diopsidic. The augite microphenocrysts are sometimes poikilitic with inclusions of ilmenite. Augite also occurs as subhedral crystals in the groundmass, together with laths of labradorite, and small flakes of biotite.

The feldspar porphyrites have a panidiomorphic texture. The phenocrysts are oligoclase-andesine, often poikilitic, enclosing small flakes of green mica. The groundmass consists of euhedral to subhedral andesine, hornblende, magnetite and ilmenite. In some specimens from dykes at Clover Dam the hornblende occurs as glomerophenocrysts. A more acid type occurs on the summit of Mt Bogong. Euhedral phenocrysts of sericitized feldspar are 1 mm long. Hornblende and euhedral quartz also form phenocrysts; the quartz sometimes has embayed margins, but otherwise there is no evidence of reaction between the quartz and the groundmass, and the quartz is no doubt primary. The groundmass is composed of feldspar, chloritized hornblende, quartz, and iron ore.

The microdiorites are characterized by a fine equigranular to subequigranular texture. Laths of calcic andesine, and euhedral to subhedral hornblende and occasionally augite, are the essential constituents, with the andesine dominant. In one specimen from the No. 4 Head Race Tunnel the augite is dominant, while in another specimen from the same tunnel some biotite is present.

The basalt dykes, which are only tentatively correlated with the lamprophyres, have olivine and diopsidic augite with laths of labradorite as the essential constituents. The texture varies from microcrystalline to cryptocrystalline. Primary calcite is present, and some magnetite is accessory. The monchiquites have a microcrystalline subequigranular texture. Augite, usually diopsidic, but sometimes titaniferous, forms laths up to 0.5 mm long. Olivine is abundant and has been partially replaced by serpentine. Labradorite is a minor constituent, but magnetite is abundant.

Metasomatism has been active in all of the dykes examined. Where the dykes have been sheared, the metasomatic effects are extreme. The writer has not been able to confirm in general the observations of Baker (1950) that the dykes have not been sheared. The chief effects of metasomatism have been the saussuritization of the feldspars, and frequently, the replacement of this material by clinozoisite. Clinozoisite has frequently replaced biotite, hornblende and augite, and secondary pyrite, chalcopyrite, magnetite, quartz, and calcite have been introduced.

ACID DYKES

Five types of acid dyke were recorded in the area: granodiorite aplite, microgranodiorite, granophyre, pegmatite, and granodiorite porphyrite. The granodiorite aplites have a fine saccharoidal texture, and are composed of quartz, oligoclase in excess of orthoclase, and rare biotite. On the summit of Mt Bogong, a type with abundant euhedral almandine was recorded. Secondary pyrite is sometimes present. The microgranodiorites are rare. These have almost the same composition as the granodiorites, but biotite seems to be reduced. The granophyres are biotite rich types, with the texture typically granophyric. Phenocrysts of biotite and oligoclase occur in a finely crystalline groundmass of quartz, orthoclase, biotite, and rare

TABLE 9
Analyses of Lamprophyre Dyke Rocks

	1	2		3	4	5
SiO ₂	53.46	51.45	Quartz	—	—	1.8
Al ₂ O ₃	18.40	19.75	Orthoclase	4.8	tr.	1.8
Fe ₂ O ₃	2.76	0.72	Plagioclase	21.6	51.2	22.8
FeO	5.52	5.80	Biotite	—	—	1.8
TiO ₂	1.19	0.95	Hornblende	8.9	tr.	64.5
MnO	0.08	0.08	Augite	—	41.1	—
P ₂ O ₅	0.04	0.04	Matrix	61.5	—	—
CaO	4.06	7.84	Accessories	3.2	7.7	3.7*
MgO	6.05	7.32	* Secondary calcite 3.6% also present.			
Na ₂ O	1.95	2.00				
K ₂ O	1.68	1.71				
H ₂ O—	0.56	0.07				
H ₂ O+	3.36	1.45				
	99.11	99.18				

1. Spessartite, Clover Dam (Analysis by V. Biskupsky); 2. Microdiorite, Beckraith Cr. (Analysis by Biskupsky); 3. Felspar porphyrite, Clover Dam; 4. Augite lamprophyre, Mossybank, Pretty Valley; 5. Spessartite, Clover Dam.

muscovite. In the granodiorite porphyrite phenocrysts of biotite and oligoclase occur in a groundmass of quartz, oligoclase-andesine, rare orthoclase and biotite. The pegmatites are very coarse grained. Intergrowths of quartz and orthoclase perthite are typical. Muscovite may be present, but biotite is always absent. Euhedral almandine and tourmaline may occur, and on Mt Bogoug, one specimen contains tantalite.

CATACLASTIC ROCKS

The mylonites and cataclasites of the Kiewa area have already been described (Beavis 1961). These rocks are associated with the older faults of the area. Associated with many of the younger faults are incoherent cataclastic rocks, the most important of which are gouge, breccia, and fault conglomerate. Brecciated mylonite and cataclasite, due to renewed movement on old faults are not uncommon. The breccias consist of lens shaped fragments of varying dimensions, but generally with a maximum length of 6 in. These lenses are separated by thin seams of gouge up to 5 mm thick. The faces of the lenses are polished and slickensided. Little change has been noted in the composition of the rocks except that immediately adjacent to the faces, the feldspars may be sericitized, and the micas 'smeared'. There is however a preferred orientation of the quartz crystals on the faces.

Fault conglomerate was observed only once. This was cut by the No. 4 Tail Race Tunnel over a length of 300 ft. The rock affected was a permeation gneiss intruded by lamprophyre dykes. Boulders of both gneiss and lamprophyre were recognized in the conglomerate. The boulders, up to 5 ft in diameter are well rounded, with the surfaces strongly slickensided. The matrix is black, very fine material. The smaller particles were monomineralic, often clay size, but particles greater than 1.17 mm were recognizable rock fragments. Secondary calcite had partially cemented the matrix.

The gouge contains a number of minerals, including chlorite, indicative of slow movement, with relatively low pressures and temperatures. The X-ray pattern of a gouge from Mt Beauty is shown on Table 10.

TABLE 10
X-ray Powder Pattern: Gouge

I (est.)	2	1	8	4	9	7	8	1	5	3	2	2	1
d (kx)	14.01	9.82	6.97	4.66	3.55	3.30	3.02	2.88	2.59	2.49	2.30	2.03	1.96

THE BOGONG VOLCANICS

BASALTS AND LIMBURGITES

The basaltic rocks are strikingly uniform in composition, with olivine basalts predominating. Basal flows are generally more basic, comprising limburgites and limburgitic basalts. Associated with the basalts are plugs and dykes of phonolite and tinguaite, and dolerite dykes.

RUINED CASTLE

The lower flows have a microporphyritic texture, with glomeroporphyritic texture locally developed. Flow structure is seen only at the top and base of the individual flows. Augite, olivine and labradorite occur as phenocrysts. The olivine, a forsteritic type, is frequently replaced by serpentine, or very rarely, by iddingsite. The augite is diopsidic, with $2V = 50^\circ$, although some pale mauve augite with $2V = 60^\circ$ also occurs. The augite is frequently twinned, sometimes zoned, and may be poikilitic. In one specimen reaction has occurred between analcite and augite to produce aegerine. Local limburgitic basalts have less felspar and a greater proportion of mauve augite. In these, halloysite and calcite occur sporadically.

In the upper flow, augite, olivine and labradorite occur as phenocrysts in a cryptocrystalline to glassy matrix. The olivine is sometimes replaced by iddingsite. Brown diopsidic augite is commoner than mauve augite, but the latter occurs more frequently than in the lower flows.

BASALT HILL

The basal flow is a black, non-vesicular limburgite, with olivine and zoned diopsidic augite as subhedral microphenocrysts in a microcrystalline groundmass of augite, olivine, and varying, but significant, amounts of labradorite. Analcite is present as an essential constituent. The middle and upper flows are olivine basalts, the essential difference between the two being the absence of augite from the matrix of the middle flow.

MT JIM-BUNDARRAH

Seven distinct flows, each separated by tuffs and lacustrine sediments, have been recognized. With the exception of the basal flow (flow 1) and localized sections of higher flows, all are olivine basalts. The limburgite of flow 1 outcrops around the margin of the outlier, with the best exposures near the Niggerheads and at Dibbin's Lookout. Phenocrysts of diopsidic augite, 2 mm long, and generally euhedral, are set in a matrix of augite, olivine and magnetite; minute laths of indeterminate felspar and grains of analcite are also found in the matrix.

The basalt of flow 2 is a dark coloured, non-vesicular rock, with laths of labradorite 0.75 mm long, abundant. Anhedral microphenocrysts of diopsidic augite have an outer zone of mauve augite. Olivine has been partly replaced by serpentine. The matrix is green in colour, and varies from cryptocrystalline to glassy. The basalt of flow 3 is similar, except that near the base of the flow, the augite is colourless, and

is restricted to the matrix, while the olivine has been iddingsitized. Olivine is the only mineral in the basalt of flow 4 which occurs as phenocrysts. It may be replaced by iddingsite, but more commonly by serpentine. Limburgitic types are present in this flow. In flow 5, olivine occurs as subhedral phenocrysts, together with pale brown augite, showing hour glass structure. The augite tends to a glomeroporphyritic habit. The augite of flow 6 is similar, but in this flow, labradorite often constitutes the bulk of the phenocrysts. In the uppermost flow, flow 7, the feldspar is restricted to the matrix.

The Young's Hut outlier has been intensely faulted. While certain correlation with a particular flow of the main outlier is impossible, it has affinities with flow 2. Phenocrysts of diopsidic augite with an outer zone of mauve augite are 1 mm long, while microphenocrysts of titanaugite are abundant. The olivine has been replaced completely by iddingsite. Labradorite is restricted to the matrix.

MT FAINTER

This basalt has a microporphyritic texture, with olivine the only mineral occurring as microphenocrysts; these are subhedral, and up to 0.75 mm long. Most are unaltered, but some are partially serpentinized. The augite is diopsidic, and forms laths, the orientation of which impart a flow structure to the rock. A little glass is present in the matrix.

MT LOCH

Euhedral, frequently twinned phenocrysts of augite are 2 mm long, with a tendency for the augite to have a glomeroporphyritic habit. Olivine, with some serpentine along the cleavage planes also occurs as phenocrysts. Iddingsite after olivine is rare. The matrix is composed of augite, olivine, magnetite, labradorite, and brown glass.

ROPER'S LOOKOUT

The basalt here is notable for the xenocrysts of quartz, and the poor development of augite. It is fine grained, rarely glassy, with microphenocrysts of olivine in a groundmass of olivine, labradorite, and magnetite. In the vesicles of the scoria of this plug, natrolite and halloysite occur.

ROCKY CREEK

Intense alteration of the basalt of this neck makes determination of the original constituents difficult. The texture is porphyritic, with the original olivine phenocrysts now replaced by serpentine. The only mineral not altered is the diopsidic augite. The feldspars have been replaced by a fine, clay like mineral. Calcite and analcite fill the numerous vesicles.

DOLERITE DYKES

Dolerite dykes, tentatively correlated with the basalts are exposed more or less uniformly throughout the area. They have a subequigranular, ophitic texture, with intergrowth of laths of labradorite, and euhedra of strongly pleochroic titanaugite. Analcite and ilmenite are essential constituents. Primary calcite has reacted to form ferrocaltite, a green fibrous mineral. One dolerite from the No. 4 Head Race Tunnel contains significant amounts of serpentinized olivine; in this rock the laths of feldspar contain needles of aragonite.

ALKALINE ROCKS

Two tinguaitite dykes were mapped: one on Timm's Lookout (Crohn 1949), and one in Big R. The texture is microporphyritic, with subhedral phenocrysts of alkali feldspar 1 mm in diameter. Aegirine is restricted to the groundmass as needles and minute equidimensional crystals. In some sections, alteration has been intense, with the feldspar sericitized, and the aegirine chloritized. Calcite has replaced the little nepheline which was originally present.

The phonolite of Mt Smythe is a dark coloured, dense, microporphyritic rock. Orthoclase occurs as subhedral phenocrysts and as 'streaks' of microcrystalline aggregates. Nepheline forms euhedral phenocrysts, and also occurs as laths in the matrix. Radiating aggregates of aegirine are common. The matrix is cryptocrystalline, and cloudy due to alteration.

Analyses of volcanic rocks are shown on Table 11. In addition to the chemical analyses, many modal analyses were completed. These showed a high proportion of matrix, and were of little value. The main conclusion drawn from the modal analyses (Beavis 1960) were that magnetite and olivine were more abundant near the bases of flows, but not appreciably so. The modal evidence was of no value in assessing the importance of oxidation processes at the surface and base of flows, nor in correlating the flows of one outlier with those of another.

TABLE 11
Chemical Analyses of Volcanic Rocks

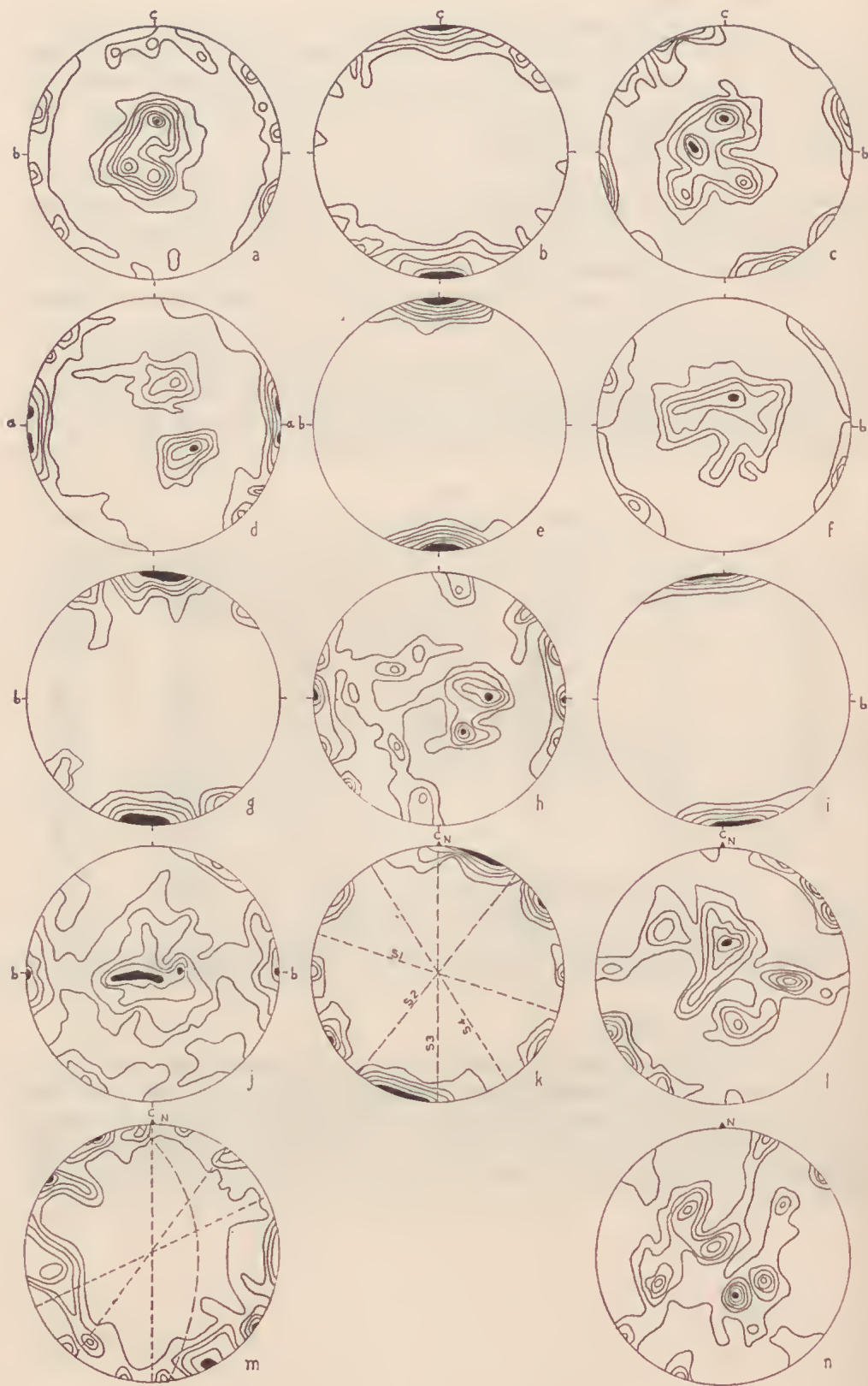
	1	2	3	4	5	6
SiO ₂	59.22	46.90	46.59	46.85	44.22	45.03
Al ₂ O ₃	21.36	17.89	17.64	17.75	19.00	16.05
Fe ₂ O ₃	2.86	0.06	0.06	0.12	1.75	1.41
FeO	0.32	8.10	7.92	8.08	7.20	7.56
TiO ₂	—	1.58	1.42	1.40	1.48	1.65
MnO	0.11	0.10	0.10	0.09	0.68	0.09
P ₂ O ₅	0.02	0.08	0.05	0.07	0.05	0.22
CaO	1.25	9.26	9.14	9.19	6.93	9.36
MgO	tr.	9.63	9.90	9.84	5.50	12.99
Na ₂ O	4.60	2.35	2.15	2.09	1.65	1.70
K ₂ O	4.32	1.84	1.54	1.75	1.06	1.34
H ₂ O—	0.65	0.38	2.20	0.70	3.00	0.62
H ₂ O+	4.85	1.54	0.45	1.60	7.62	1.48
	99.56	99.79	99.20	99.53	99.54	99.50

Analyses: V. Biskupsky

1. Phonolite, Mt Smythe; 2. Basalt, Ruined Castle; 3. Basalt, Mt Jim; 4. Basalt, Basalt Hill; 5. Dolerite, No. 4 Head Race Tunnel; 6. Limburgite, Dibbin's Lookout.

PETROFABRIC ANALYSES

A total of 50 petrofabric analyses of greywacke, schist, permeation gneiss, gneissic granodiorite, granodiorite and mylonite have been made, of which some have previously been discussed (Beavis 1961). For each rock, both quartz and mica fabrics were examined where possible. The petrofabric studies were aimed at supplementing other data for the petrogenic and structural research. The analyses are shown on Fig. 4.



A single macrolineation is present in the greywacke (b//B) and is horizontal. The infrequency of mica in the greywacke restricted the analysis to quartz. The quartz diagram, Fig. 4a, shows two well marked features: statistical maxima for the *c* axes of the quartz lying on *h0l* planes, more or less symmetrically disposed about *ab*, as well as the development of a partial girdle.

In the schists, lineation is developed to varying degrees. It is most prominent in the knotted schists where it is formed by the long axes of the knots on the weathered surface. It is least well developed in the low grade schists. An important aspect of the fabric of the schists is the lack of any but local deformation. The biotite diagrams for both schists examined have maxima in *c*, the biotite lying in the plane of the foliation. The three quartz fabrics show some differences. The low grade schist shows a partial *ab* girdle for the *c* axes, as well as two strong and one weak point maxima about *a*. The knotted schist shows an even less complete *ab* girdle, and a single point maximum. In the quartz schist, a strong *ac* girdle is present, with a maximum in *a* and two point maxima, one strong, one weak, on either side of the *ab* plane, i.e. on *Ok* planes.

The quartz diagrams show no clear evidence of a tectonite orientation, and it seems unlikely that the orientation of either the biotite or the quartz is due to deforming movements either during or after their recrystallization. The fabric indicates a crystallization schistosity, the orientation of the mica being a mimetic emphasis of a pre-recrystallization *s* plane. As pointed out by Knopf and Ingerson (1938) the crystallization in this fabric does not create *s* planes by changing the shape of pre-existing grains; it merely emphasizes an *s* plane that is already present. This idea also finds support in the field evidence that the foliation of the schists is parallel to the original bedding of the sediments, and that the recrystallization was mimetic.

Two specimens of permeation gneiss were examined: in both lineation was poorly developed. One from Clover Dam was also poorly foliated, but the other, from the No. 4 Head Race Tunnel showed a strong foliation and banding. In both cases, the biotite diagrams show maxima in *c*, and agree closely with the biotite fabrics of

FIG. 4—Petrofabric Analyses.

- a. 200 *c* axes of quartz, greywacke, Mt St Bernard. Contours 8-7-6-5-4-3-2-1% per 1% unit area.
- b. Poles to 110 cleavage planes in biotite, low grade schist, Cobungra Gap. Contours 11-9-7-5-3-1%.
- c. 212 *c* axes of quartz, same specimen as b. Contours 6-5-4-3-2-1%.
- d. 287 *c* axes of quartz, quartz schist, Mt Nelse. Contours 5-4-3-2-1%.
- e. Poles to 200 cleavage planes in biotite, knotted schist, Mt Nelse. Contours 15-10-5-4-3-2-1%.
- f. 179 *c* axes of quartz, same specimen as e. Contours 5-4-3-2-1%.
- g. Poles to 200 cleavage planes in biotite, permeation gneiss, Clover Dam. Contours 10-8-6-4-2%.
- h. 103 *c* axes of quartz, same specimen as g. Contours 7-5-3-2-1%.
- i. Poles to 200 cleavage planes in biotite, permeation gneiss, No. 4 Head Race Tunnel. Contours 10-8-6-4-2%.
- j. 300 *c* axes of quartz. Same specimen as i. Contours 5-4-3-2-1%.
- k. Poles to 300 cleavage planes in biotite, gneissic granodiorite, Pretty Valley. Contours 6-4-3-2-1%.
- l. 187 *c* axes of quartz, same specimen as k. Contours 7-5-4-3-2-1%.
- m. Poles to 300 cleavage planes in biotite, granodiorite, No. 1 Power Station, Contours 10-8-6-4-2%.
- n. 200 *c* axes of quartz, same specimen as m. Contours 6-5-4-3-2-1%.

the schists. The quartz diagrams both show *ab* girdles, the girdle for the well foliated gneiss being more fully developed than that of the weakly foliated rock. Concentrations within these girdles occur in, or close to *a* and *b* of the fabric. As in the case of the schists, a non-tectonite fabric is indicated, the girdle here indicating the orienting influence of a set of parallel planes in which no one direction controls the movement. In this type of fabric, the planar surface does not control the direction of growth, nor actively guide the course of deformation, but acts passively by furnishing surfaces along which solutions were able to move freely. In such fabrics, if the solutions are free to move with equal ease in all directions within the controlling surfaces, the diagrams show, as in the present case, girdles parallel to the planes of maximum ease of movement. A criterion for such girdles is that they are normal to *c* of the fabric, rather than to *a* or *b* as in the case of tectonites.

In the hand specimen, only one *s* plane is visible in the gneissic granodiorite (*s*₁ of Fig. 4k). The biotite diagram indicates four *s* planes, however, all more or less equally developed. The interpretation of the quartz diagram is difficult, but there appears to be a tendency to girdle development. On the evidence of the fabric, the most important orienting mechanism seems to have been shearing stress. This is discussed more fully later in the paper.

Except locally, no macrofoliation was observed in the granodiorite. The study of a single set of sections from the No. 1 Power Station, showed girdles in the biotite with strong point maxima, suggesting the presence of three *s* planes, two of which are vertical, and one with a steep easterly dip. The possibility that one of these may represent primary flow cannot be excluded. Comparison of the diagrams with those of the macrofracture patterns show that there is apparently no relationship between the two. As in the case of the gneissic granodiorite, the quartz diagrams are difficult to interpret; comparison with the biotite diagrams is the only basis for study, possibly indicating that the quartz maxima lie on *h0l* planes which can be related to the *s* planes of the biotite diagrams. This suggests the orienting influence of shearing, and while not a satisfactory explanation is the one which best fits the data.

PETROGENESIS

The field and petrographic evidence indicate a close genetic relationship between the schists and the permeation gneiss. Joplin (1952) recognized six stages in the metamorphism and granitization of the Cooma Complex: regional metamorphism; superimposed thermal metamorphism; permeation, without addition from a magma; addition from an attenuated magma; formation of a potassic wave front; and finally, the injection of the magma as concordant intrusions. Tattam (1929) noted the essentially thermal nature of the metamorphism. The parallelism of bedding and foliation at Kiewa, and the absence of axial plane foliation indicate the importance of non-dynamical recrystallization (cf. Fairbairn 1935). The mimetic fabric of the schists is further evidence of non-dynamical recrystallization.

Kyanite and andalusite zones are absent, any andalusite being restricted to the contact zones of later intrusions. The relatively early appearance of sillimanite is also due to later intrusions. The apparently retrograde metamorphism indicated by the pinitization of cordierite in the zone of knotted schists is significant. It is almost certainly the result of reaction with aqueo-potassic material (Tattam 1929) and is to be regarded as evidence of the potassic wave front postulated by Joplin at Cooma.

Examination of the analyses presented earlier, as well as those presented by Tattam (op. cit.) show little significant addition during metamorphism. The composition of the permeation gneisses is essentially granitic, and it seems probable that the gneiss originated in the soaking of the schists with granitic magma. The

pegmatitic lenses of the gneiss are also to be regarded as representing magmatic addition. There is evidence at Kiewa that most of Joplin's stages can be recognized. There is no evidence of the final stage of concordant intrusion. What Joplin meant by 'permeation without addition' is difficult to understand, and at Kiewa, there is certainly no evidence of such a process.

The field evidence has shown that the gneissic granodiorite is the oldest of the intrusives, but the age difference between this rock and the non-foliated granodiorite is very small. The marginal features of the gneissic granodiorite as well as the foliation, suggest comparison with the gneiss of the Scottish Highlands described by Barrow (1893). Barrow concluded that the gneissic structure was due to shearing stress applied at the late magmatic stage, the stress also resulting in the transfer of the still liquid part of the magma to the margins of the mass where it crystallized as dykes. The petrofabric evidence at Kiewa indicates shear, and, with the complete absence of strain in the minerals, it seems clear that the shearing stress was operative at a stage when the crystals were capable of dimensional orientation, but without any deformation of the crystal lattices; i.e. at a stage when part of the magma was still in the liquid condition. This tends to be supported by the dissimilarity between the biotite and quartz fabrics, particularly if the crystallization of the quartz was not completed until after the cessation of shear.

The macrofoliation of the gneissic granodiorite corresponds to one of the directions of shearing of the Bowring deformation. The parallelism of the dykes and schist rafts to the foliation of the gneiss also suggests shear at the time of the intrusion of the mass. Consideration of the microfabric shows four *s* planes, one of which is parallel to the macrofoliation. If we consider the case of the magma in a plastic state, confined between two relatively rough walls, an analogy can be drawn with the ideal case of a plastic fluid confined between rough plates which are approaching each other due to a compressive stress (Fig. 5).



FIG. 5—Development of foliation in gneissic granodiorite.

Jaeger (1956) gives the differential equations to the planes of slip developed in the fluid under these conditions, and these planes are shown in Fig. 5. Superimposed on the diagram are the s planes of the gneissic granodiorite. The orientation of the compressive stress in Fig. 5 is that of the Bowring Orogeny. It can be seen that the s planes of the gneissic granodiorite are represented by the slip planes of the ideal case. The foliation of the gneissic granodiorite may be regarded therefore as due to shear within the partially crystallized magma, resulting from a compression on the walls of the magma.

Variations in the non-foliated granodiorites are considerable. Such variations appear largely, but not solely, to be due to shear and metasomatism. Where normal intrusive contacts could be studied, there was evidence of local contamination. Apart from this, there was noted a marked increase in the proportion of hornblende towards the northern (and deeper) sections of the East Kiewa granodiorite. The aplites and pegmatites associated with the granodiorites are to be regarded as late magmatic phases. That the granodiorites are normal intrusive types is certain; no evidence to suggest granitization was observed.

The Big Hill quartz diorite differs from other rocks of this type described by Edwards (1939) from North Eastern Victoria, in the total absence of pyroxenes. Edwards postulated a two pyroxene magma with, initially, two immiscible pyroxenes, diopsidic augite and hypersthene, crystallizing out. At a later stage, a single hornblende crystallized out in place of the pyroxenes, and by a discontinuous reaction, the two pyroxenes were replaced by hornblende. The quartz diorite of Granite Flat has green brown hornblende crystals enclosing colourless augite and hypersthene. Some of the melanocratic lamprophyre dykes at Kiewa show this feature, except that the enclosed pyroxene is invariably augite $2V = 50^\circ$. If Edwards's idea is accepted, then the Big Hill quartz diorite is to be regarded as the final product of the differentiation process.

Edwards relates the intrusion of the quartz diorites with the granodiorites as well as with the extrusion of acid lavas in Eastern Victoria. This idea cannot be supported on the evidence from Kiewa. Highly acid and alkaline differentiates are rare at Kiewa, being restricted to small marginal granites and syenites. The lamprophyres are almost certainly comagmatic with the quartz diorite, and are basic differentiates of the quartz diorite magma.

The hornblende rich schlieren which are restricted to the higher levels, show no evidence of origin from assimilated gneiss or other older rocks in the area, and are obviously primary flow structures. The present exposed upper surface of the intrusion, on this evidence, is therefore close to the original roof.

The mineralogy of the basalts and of the related alkaline rocks is remarkably uniform, and demonstrates the derivation of the lavas from an olivine basalt magma. Differentiation of the basalt magma proceeded normally to the late stages, when large volumes of lime and iron carbonates were released. These soaked the tuffs, Tertiary sediments, the more pervious basalts, and shear zones in the older crystalline rocks with calcite and siderite.

The possibility that some at least of the melanocratic dykes of the area were related to the basalts was investigated. The basalt and monchiquite dykes have affinities with both the basalts and the quartz diorites. The dolerites, however, are certainly to be correlated with the basalts, since dykes of this type intrude Jurassic rocks in South Gippsland (Edwards 1934). Titaniferous augite is the characteristic pyroxene of the three dyke rocks, while the augite of the lamprophyres is generally diopsidic. The titanaugite is to be regarded, however, more as an indicator of

temperature conditions in the magma chamber, than as evidence of consanguinity with one or other of the two magmas.

Structural Geology

The data on which the structural work has been based included some 8,000 field contact measurements. The application of statistical techniques, necessary because of the monotonous lithology, was possible, therefore, with little chance of error due to inadequate observation. Compensation for poor surface exposures was found in the detailed sections provided in the 6 miles of tunnel constructed during the period in which the area was studied.

FOLDING

Bedding is the only strong surface uniformly developed in the Upper Ordovician sediments in the area; the cleavage of the slates is usually, but not invariably,

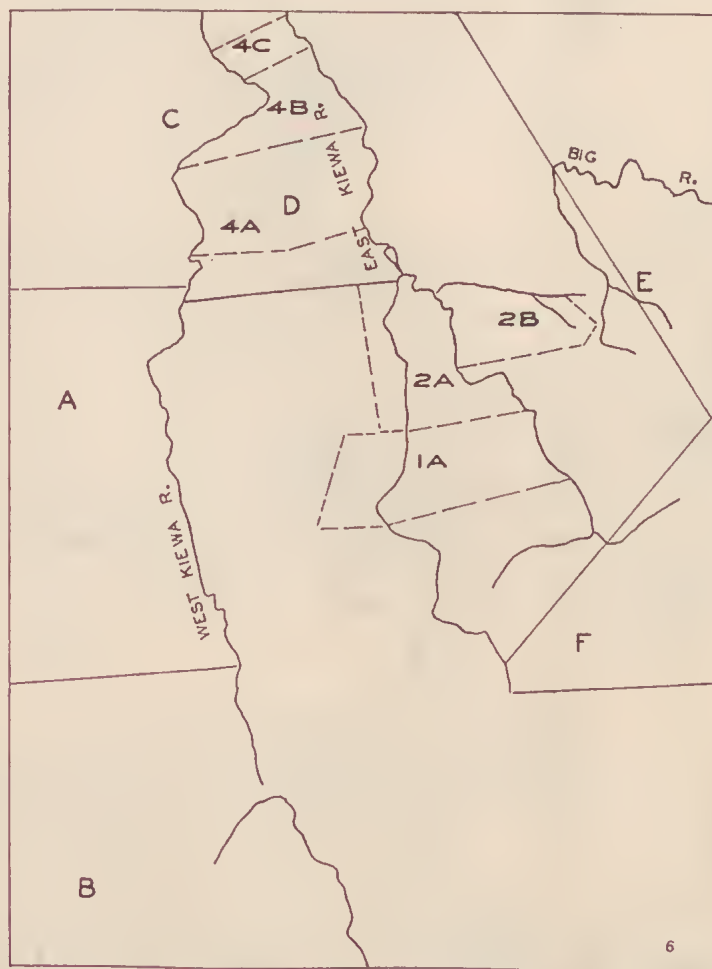
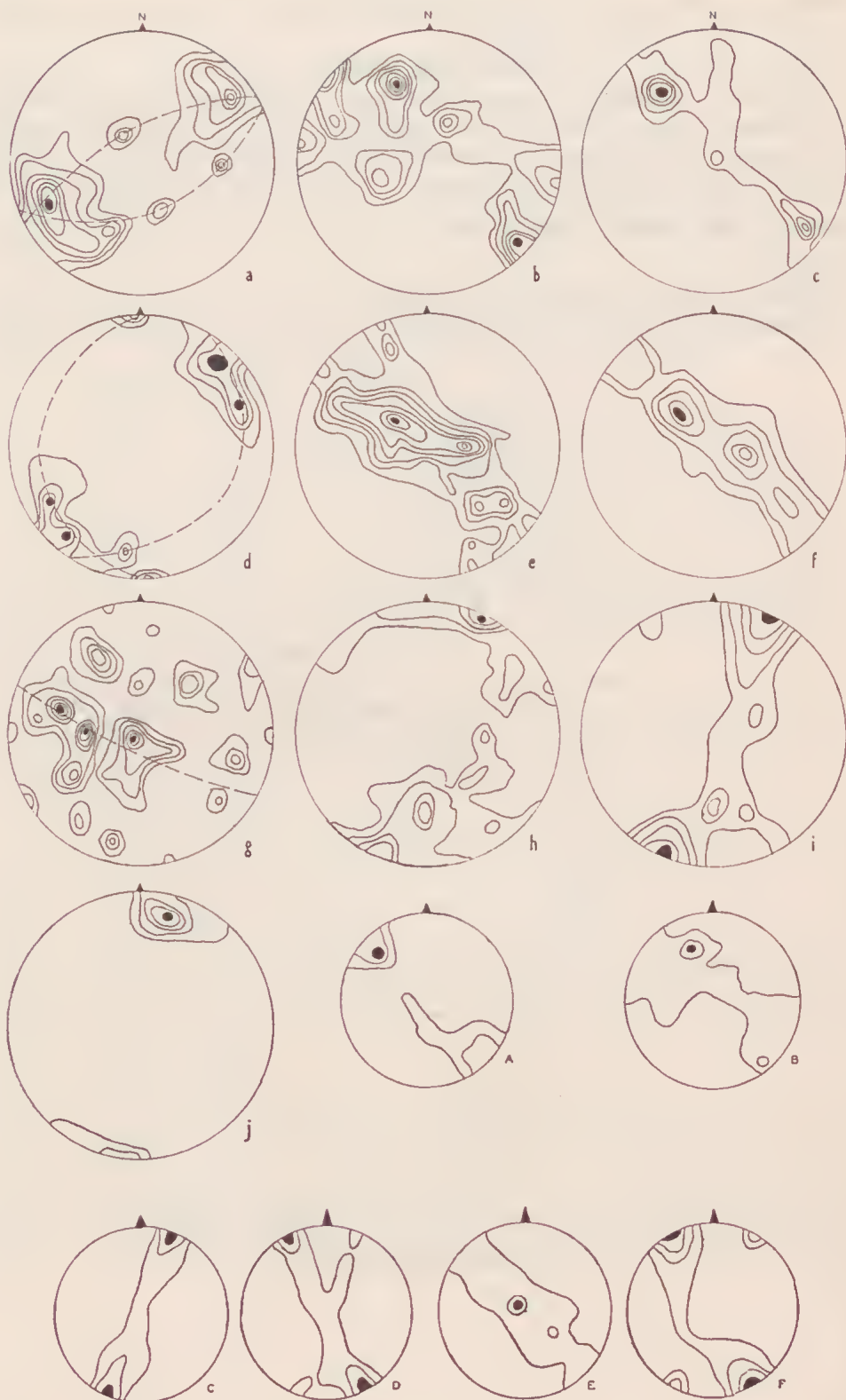


FIG. 6—Index Map, Structural Studies.



parallel to the bedding. In the SW. sector, the trend of the fold axes is uniformly N.40°W. to N.60°W., but towards the N., a strong westerly swing occurs. Dip of the beds is predominantly N.-easterly, but S.-westerly dips are not infrequent. Only minor folds were recorded, with axes at intervals of 400 to 500 ft. The folds are characteristically sharp, but not acute. Lineation parallel to the fold axes is strongly developed as minute puckers on the bedding planes. The lineation has dominant plunge 35°NW., although plunge 15°SE. is also important.

The field impression that N.-easterly dips predominate is confirmed by the π diagram of Fig. 7a. This diagram may be interpreted as suggesting that the sediments mapped occupy an E.-dipping limb of an anticlinorium or synclinorium, a type of folding characteristic of the lower Palaeozoic beds which have been mapped in detail further to the W. Alternatively, the beds may be regarded as the limb of the main Kiewa Anticline, the dominant fold structure of the area. The β diagram and the B diagram (Fig. 7b,c) show two distinct maxima, with $\beta_1 = B_1$ and $\beta_2 = B_2$. Several interpretations are possible. The first, in accordance with Sander's ideas, is that there have been two foldings. However, the diagrams suggest, rather, either a doming structure, with reversal of plunge, or 'splitting' of folds similar to that described by Thomas (1953) at Chewton. If the idea of doming is valid, more horizontal β axes would be expected than were actually recorded; moreover, doming would be expected to produce β maxima normal to those recorded. Detailed field mapping in areas where exposures were suitable suggested that the concept of the splitting folds is the more acceptable.

In the Mt St Bernard-Mt Blowhard area, the splitting of folds may be observed (Fig. 8a). Small folds may be seen to develop on the limbs of the larger folds, the dimensions of the small folds increasing along the strike. The first sign of development is the terracing of the limbs, these terraces passing into recognizable anticlines and synclines within distances of as low as 50 ft.

The nature of the sediments, together with a consideration of the geological history of the area, suggest that the sediments, once folded, would at the time of later deformations, be in a more or less brittle condition. These rocks would then not be expected to undergo further folding, and deformation by fracture during the later orogenies was more likely. Within the sedimentary belt mapped, failure by fracture is seen adjacent to the West Kiewa Thrust and the Tawonga Fault. In the former case post-folding deformation is seen in shear zones more or less parallel to the fault, and to the fold axes, the shears increasing in frequency and intensity easterly from Mt St Bernard. In the case of the Tawonga Fault the fold axes have

FIG. 7—Statistical Diagrams of Folding.

- a. π Diagram, Ordovician Sediments. 356 points, contours 8-6-5-4-3-2-1%.
 - b. β Diagram, Ordovician Sediments. Contours 7-6-5-4-3-2-1%.
 - c. B Diagram, Ordovician Sediments. 118 B axes, contours 5-4-3-2-1%.
 - d. π Diagram, Schists. 268 points, contours 4-3-2-1%.
 - e. β Diagram, Schists. Contours 8-7-6-5-4-3-2-1%.
 - f. B Diagram, Schists. 260 B axes, contours 5-4-3-2-1%.
 - g. π Diagram, Permeation Gneiss. 600 points, contours 6-5-4-3-2-1%.
 - h. β Diagram, Permeation Gneiss. Contours 5-4-3-2-1%.
 - i. B Diagram, Permeation Gneiss. 210 B axes, contours 5-4-3-2-1%.
 - j. Poles to 159 foliation planes, gneissic granodiorite, Pretty Valley. Contours 30-10-5-2-1%.
- A. - F. β Diagrams of sub areas A - F. of Fig. 6. Contours A - E 5-3-1%, F 7-5-3-1%.

been dragged to the W., but there is no variation in the plunge of the fold axes. Crushing of the sediments has occurred adjacent to the fault.

E. of the Kiewa area the Ordovician sediments have been only cursorily examined. In the Mitta Mitta Valley the folding tends to be closer and sharper than in the Kiewa Valley, while intense crumpling is not uncommon. The fold axes at Mitta Mitta have very steep southerly plunge.



FIG. 8—Folding of Palaeozoic Rocks, Kiewa.

- a. Map showing folding of Ordovician sediments, Mt St Bernard.
- b. Section A-B of Fig. 8a.
- c. Folding of Permeation gneiss, Bogong.
- d. Regional cross section showing Kiewa Anticline.

Both the field observations and the study of thin sections have shown that the foliation of the schists is parallel to the original bedding, a feature previously noted by Crohn. Lineation is usually well developed as corrugations on the foliation planes and by the dimensional orientation of mineral crystals and nodules. Folding of the schists seems to be broader than that of the sediments. The statistical geometry of the folding in the schists is shown on Fig. 7 d-f. S.-westerly dips are more important than N.-easterly. The β and B diagrams have features comparable to those of the diagrams for the sediments. Plunge of the fold axes, however, is steeper.

In the valley of Camp Cr., Mt Bogong, local isoclinal folding of the schists was observed, and adjacent to the Tawonga Fault at Mt Beauty, the schists are crumpled. Apart from these purely local features, the folding of the schists is comparable to

that of the Ordovician sediments, and in view of the nature of the metamorphism, any marked differences would be unexpected.

Studies of the foliation of the permeation gneiss have been based on the assumption that the foliation represents the bedding of the original sediments, an assumption made by Spencer (1959) in mapping comparable gneisses in U.S.A. At Kiewa, where the normal transition from schist to permeation gneiss could be studied, foliation was continuous through the transition, thus giving some justification for the assumption, which is supported also by the very obvious sedimentary structures in the gneiss. Foliation and banding are always reasonably strong in the permeation gneiss, but lineation is not always apparent. When it is present, lineation is due to the orientation of inequant mineral crystals, usually sillimanite. Fine, often complex folding (Fig. 8c), is typical, but pygmatic folding was only rarely seen. One of the most important aspects of the folding in the gneiss is the dominance of sub-horizontal foliation, a feature noted by Crohn (1949), who, however, made no attempt to assess the significance of this.

Fig. 7g-i illustrates the statistical geometry of the folding of the permeation gneiss. The π diagram illustrates the wide variety of attitudes in the foliation, and emphasizes the importance of the horizontal foliation. There is a single B maximum corresponding to the β maximum. The interesting point is that, in strong contrast to the sediments and to the schists, plunge of the fold axes is zero, and moreover, there is a strong easterly swing in the trend of the axes, which is a departure from the trend not only at Kiewa, but in the complex as a whole. This variation in trend could be due to one or more of several features: rotation of the whole of the central block at Kiewa, or to rotation of a single block from which the excess of field measurements could weight the result. In compiling the diagrams for the gneiss, between 65% and 70% of the measurements were taken in the N. part of the area. The whole of the mapped area was divided, therefore, into sub-areas, and β diagrams prepared for those areas for which at least 200 readings were available. These are shown on Fig. 7 A-F, where it can be seen that with the exception of the block (Arca C) bounded by the Tawonga and Big Hill Faults, the trends of the axes are consistently NNW. It is apparent therefore that the regional β diagram has been influenced by the great number of measurements from this subarea, in which rotation has occurred. In this subarea, the older joints, faults, and lamprophyre dykes also show an easterly rotation. Such rotation was probably not simply in the horizontal plane, but also involved rotation in the vertical plane since there is a marked flatterling in the plunge of the fold axes.

Synthesis of the regional folding cannot be attempted yet, but the study of the fold geometry at Kiewa has enabled an assessment of the fold pattern of this area to be made. N. of Kiewa, Tattam (op. cit.) showed that the dip of the sediments on both sides of the metamorphic belt is westerly, and this was interpreted as indicative of overfolding to the E. of the acutely folded sediments. At Kiewa, the sediments have a dominantly easterly dip, while the statistical evidence suggests an areal trend of the fold axes to the NNW., with gentle northerly plunge. Fig. 8d, a cross section of the Kiewa area, is an interpretation of the folding. The structure is pictured as a large, open anticline, the core of which has been migmatized. The W. limb of the fold is pictured as being sheared through on the West Kiewa Thrust, either at a late stage of the folding, or immediately post-dating the folding. The structure as a whole has a NN.-westerly plunge, although there is some general suggestion in the trend lines of the foliation (Fig. 2) that there is locally a reversal of plunge to the S.

This concept of the folding tends to regard the Ordovician sediments of the W. belt as occurring in the W. limb of the Kiewa Anticline, rather than as a limb of an entirely separate structure. If these sediments are part of the Kiewa Anticline, then this structure is almost certainly overturned to the W. Such an interpretation accounts for the predominance of easterly dips, as well as explaining the importance of the horizontal foliation in the permeation gneiss. This structure is to be regarded as the result of the development of tangential stresses from the E. during the Benambran Orogeny.

The difference in the structure at Kiewa and that further N. described by Tattam is difficult to explain, since in the former, overturning is to the W., and in the latter, to the E. It is possible that Tattam, whose prime interest was petrological, overlooked some structural data, and, at this stage, pending a structural re-examination of the area to the N., no explanation of the differences can be offered.

With the exception of the gneissic granodiorite, the intrusive rocks show only very localized and weak foliation. The foliation of the gneissic granodiorite is strong, and has a uniform attitude throughout both masses. Strike is a few degrees N. of W., with dip steeply S. (Fig. 7j). It is interesting to note that this is parallel to one of the main joint sets in the rock, and almost normal to the other joint set. The foliation of this granodiorite, as shown earlier, was the result of a stress acting from the NE. during the Bowring Orogeny. Normal granodiorites subjected to post intrusive shear have a weak foliation, generally parallel to some major shear zone cutting the rock.

FAULTING

The field work disclosed almost 1,000 faults; of these, only a few have any significance in the gross geology of the area. The faults were studied in two ways: field study of the larger and more important structures, and statistical study of the attitudes of all the faults recorded. Petrological and petrofabric studies of the cataclastic rocks (Beavis 1961) were used to determine the physical conditions of faulting.

Generally the faults are marked by crush zones of varying thickness. Average thickness was 10 ft, with extremes of less than 1 inch, and more than 1 mile. Determination of the displacement along the faults was always difficult, and sometimes impossible. Similarly, dating the fault movement was often difficult, but as a result of the statistical work, indirect methods were developed to date at least the original movement on some of the more important. Of the faults studied, both strike slip (wrench) and thrusts were recognized. Normal faults are rare.

One of the most important of the faults, the Tawonga, has been described (Beavis 1960). This a wrench fault of Palaeozoic age, on which Tertiary movement, in part low angle thrusting, occurred. Of equal importance is the West Kiewa Thrust. Howitt (1892) examined the metamorphic boundary in the Upper Dargo Valley, and recognized a normal transition, though commenting on the cataclastic nature of the schists. Crohn (op. cit.) commented on the asymmetry of the schist belts at Kiewa. Crohn offered no explanation of this asymmetry.

S. of Mt Beauty, the W. margin of the metamorphic complex is marked by a physiographic lineament occupied by the West Kiewa, Upper Cobungra, and Upper Dargo R. This lineament suggested a structural control for the W. boundary of the complex, now established between Mt Beauty on the West Kiewa, and Mayford, on the Dargo. The lineament is occupied by a zone of mylonite up to 1 mile in

outcrop width. On the W. of this zone, the Ordovician sediments have steep dips parallel to the foliation of the mylonite of the zone, and are broken by strike shears, which decrease in frequency away from (to the W.) the zone. To the E., the permeation gneiss abuts against the mylonite, the foliation of the gneiss being parallel to that of the mylonite. The foliation of the mylonite dips consistently 70° to 80° E., with strike $N.15^{\circ}-20^{\circ}$ W., parallel to the walls of the zone.

The schist described by Howitt from the Upper Dargo is a southerly continuation of this mylonite. To the N., the mylonite is terminated by the Tawonga Fault, and so far, no direct evidence of the West Kiewa Thrust has been found N. of Mt Beauty. Thomas (1949) suggested that the lower Kiewa R. may have developed on a major fault, and it is possible that mylonite may occur beneath the alluvium of the valley floor. This idea finds some support in the shearing of the low grade schists, and the occurrence of mylonite lenses, on the W. margin of the alluvium, and the gross difference in grade of the metamorphic rocks on either side of the alluvium.

The mylonite belt of the West Kiewa Valley could have resulted only from intense shearing. It is considered that this belt has developed in association with a high angle thrust, the West Kiewa Thrust. The thrusting post dated, or was contemporaneous with the folding, and pre-dated the intrusion of the granodiorites, since the Niggerheads Granodiorite intruded the mylonite. The Thrust is therefore of probable Benambran age. Renewed movement is indicated by the brecciation of the mylonites at Cobungra Gap.

A feature of considerable interest is the probable control of igneous intrusion exerted by the West Kiewa Thrust. E. of the Thrust, a number of intrusions have been mapped, whereas to the W., only a few, large, intrusive masses have been recorded. The main significance of this fault, however, is that it forms, at least in the S. sector, the W. boundary of the metamorphic complex. The nature of the boundary N. of the Tawonga Fault requires further study.

The Nelse Fault, represented in the field by a belt of mylonite with outcrop width of 50 ft, has been traced over a length along the strike of 14 miles, from Big R., S. of Glen Wills, to its termination against Spion Kopje Fault, in Spion Kopje Cr. One of the most important aspects of this fault is the displacement along it to the SE., by some 8 miles, the schist-permeation gneiss transition. In effect, in the area examined, the Nelse Fault forms the S. boundary of the schist belt.

Physiographically, the fault forms a strong lineament, with a number of small streams developed along the crush zone. Over the length mapped, the fault is almost perfectly straight, with strike $N.45^{\circ}$ W. Dip is vertical. Fabric studies of the mylonite (Beavis 1961) showed the importance of shearing stress in the faulting, and so far as can be judged from such evidence as lineation, movement was purely strike slip. Movement does not appear to have recurred; brecciation of the mylonite, typical of many of the older faults, is absent. In age, it is older than the Spion Kopje Fault against which it is apparently terminated to the NW. It may post date granitic intrusion, but this is uncertain. N. of the Spion Kopje Fault the Nelse Fault has not been certainly identified, although the fault bounding the NE. extremity of the East Kiewa Granodiorite, may be an extension.

A zone of brecciated mylonite, ultramylonite, and cataclasite up to 60 ft thick, is associated with the Spion Kopje Fault. This fault has been traced from Bogong Village easterly to Duane's Spur on the Big R. The physiographic influence of the fault is particularly strong, Spion Kopje Cr. occupying the crush zone for almost the entire length of the stream. The average strike of the fault is E.-W., with average dip vertical, but there are marked variations in both strike and dip. Displacement

along the fault does not appear to have been great, since the E. margin of the East Kiewa Grandodiorite has been displaced less than $\frac{1}{2}$ mile where it has been cut by the fault. On the other hand, the granodiorite cut by the Spion Kopje Fault in Tiger Snake Gap, Big R., has not been matched S. of the fault.

The age of the Spion Kopje Fault is possibly Bowning, since its trend corresponds with one of the statistical trends of shears developed by this orogeny. Later movement occurred, with brecciation of the older cataclastic rocks. The age of the latter movement is unknown, but it may have been that of the late movement on the Tawonga Fault.

One of the best exposures of the Bogong Fault, which has been traced from Little Bogong to Bald Hill, a distance of 8 miles, is seen where it crosses the spur rising to Mt Arthur S. of Bogong Cr. saddle. Here, mylonitized and brecciated gneiss is exposed over a width of more than 200 ft. The strike varies, but is generally NE. Dip is vertical. It is to be noted that the Bogong Fault forms the NW. boundary of the East Kiewa granodiorite, and the SE. boundary of the Big Hill quartz diorite. If a sinistral strike slip of 2 miles is assumed, it is seen that the two rock masses could originally have been in contact, suggesting that possibly the quartz diorite was intrusive into the granodiorite. Unfortunately, any contact phenomena which might give credence to this hypothesis are absent, although it is possible that these were destroyed during mylonitization. At the margin of the granodiorite there are a few poor exposures of a rock very rich in hornblende, and these may represent remnants

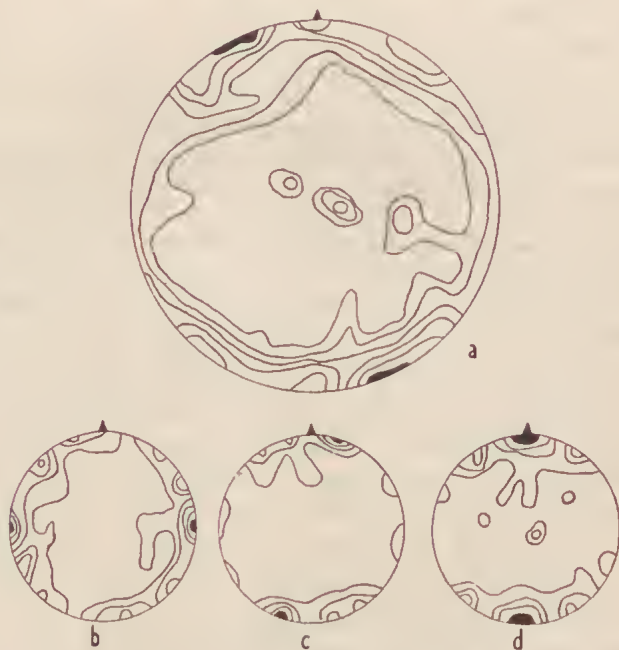


FIG. 9—Fault patterns in the Kiewa Area.

- a. Poles to 940 faults in the area. Contours 6-5-4-3-2-1%.
- b. Poles to 208 faults, sub area 1A of Fig. 6. Contours 5-4-3-2-1%.
- c. Poles to 275 faults, sub areas 2A and 2B. Contours 4-3-2-1%.
- d. Poles to 350 faults, sub areas 4A, 4B, 4C. Contours 4-3-2-1%.

of the quartz diorite. Lacking more positive evidence the possible contact of the two intrusive masses must be regarded as little more than speculation.

Several very strong faults with some interesting features, but lacking the significance of those described, have been studied. The Sassafrass Creek Fault is a high angle thrust of restricted extent, marked by a belt of brecciated mylonite 400 ft thick. Bores along the fault recorded alluvials at depths of up to 110 ft, suggesting that these were involved in the latest movements. Where the alluvials are exposed near the fault, the maximum thickness is 20 ft. The fault strikes E.-W., with dip 65°N. The best exposure of this fault is in Howman's Gap, where movement was a maximum of 200 ft. Along the strike from here, both to the E. and W., displacement appears to have diminished rapidly.

The Tail Race Fault, natural exposures of which are infrequent, was first recorded in the No. 4 Tail Race Tunnel between chainage 4,450 and 4,748 ft. The material of the crush zone is a fault conglomerate. Strike is N.-easterly, dip vertical. The fault conglomerate has been recognized only sporadically at the surface.

The trend of the major faults varies, but a N.-easterly trend is dominant, with E.-W., and S.E. less important. This applies more or less for the area as a whole (Fig. 9). It can be seen that the great majority of the faults are steeply dipping. The field work suggested some marked variations in the fault pattern from place to place throughout the area. To investigate this apparent variation, the areas in which most detailed work was done were divided into sub areas, each dominated by a major fault. Patterns were analysed for each of three sub areas: the results of the analyses are shown in Fig. 9 b-d, and in Table 12.

TABLE 12
Variation in Fault Patterns, Kiewa

Sub area	Main Trend	Subsidiary Trends	
4	90°	N.52°E.	S.55°E.
2	S.77°E.	N.56°E.	N.75°E.
1	N.-S.	N.48°E.	N.74°E. S.26°E.

Examination of each of the sub areas shows some interesting relationships. E.g. the No. 4 area is dominated by the Tawonga Fault; the fault system is regular, with one subsidiary set of faults more or less parallel to the Tawonga Fault. An equally important aspect is the symmetry, the main set, striking E.-W., making angles of 38° and 35° with the subsidiary sets.

In the No. 1 area, a comparable, but less striking symmetry is found. Here the major set, striking N.-S., makes angles of 26° with two of the subsidiary sets, but 48° with the third. Sassafrass Creek Fault, the most important structure in this area, does not appear significantly to have influenced the overall fault pattern. The Turnback Creek Fault has a set of associated minor faults, the pattern of which has the same relationship to the main fault as that observed for the Spion Kopje Fault system.

In the No. 2 area, the main set of faults is parallel to the Spion Kopje Fault, and although there is a certain symmetry with the minor sets, this is not as impressive as in the other cases examined.

The relationship between major faults and adjacent minor, possibly syngenetic, faults, was studied in some detail at the No. 1 Underground Power Station. A total of 155 minor faults was mapped in an area of 20,000 sq. ft. A single strong maximum

was found, with strike N.-S., dip 90° . Very weak sets with steep dips, with strikes N. 32° E. and N. 40° W., and a set of flat faults were recorded. The main structure, the Power Station Fault, has strike N. 80° W. and variable dip (more or less vertical). Minor structures parallel to the main fault are rare, and most intersected the main fault at angles of 20° , 32° , and 42° . There is here, thus, no clear relationship unless, as shearing proceeded on the main structure, rotation of one set of minor faults took place, as a second set was developed.

Overall, it is clear that on a broad scale, the pattern of minor faults can be related to the major fault in only isolated cases, and in most, no relationship can be proved.

JOINTING

Jointing was studied in terms of the patterns in individual rock types, variation in patterns, independently of rock type, and the regional patterns. Three genetic classes of joints were recognized: contraction joints, tectonic joints, and erosion joints. The erosion joints, or sheeting, due to elastic recovery of the rock with erosional unloading, appeared in some cases to have developed on tectonic joints, and complete separation was not always possible. Flat tectonic joints were observed in tunnels at depths of 1700 ft, where sheeting would not be expected to have occurred.

Columnar jointing is highly developed in all of the basalts. The columns vary in diameter from 3 inches to over 2 ft, and with one exception, the columns are more or less vertical. At Ruined Castle, a wide variety of attitudes was recorded, with horizontal columns at the W. end, and elsewhere plunging at 60° in various directions. The deviations from vertical were always found in association with faults. Primary joints were not recognized in any other rocks in the area, though almost certainly, some are present.

Sheeting was observed both in natural outcrops and in excavations; it was invariably accompanied by seams of decomposed rock. The sheeting was always sub-parallel to, and less steep than, the natural surface. Where sheeting outcropped on steep slopes, it tended to control the stability with respect to sliding of such slopes. This was seen at Clover Dam. Sheeting has developed independently of rock type, cutting across geological boundaries with little or no deflection; similarly, the sheeting was observed to cut across faults and tectonic joints without deflection. The seams of weathered rock found on the sheeting increased in thickness rapidly with the excavation of the overlying rock: at Clover Dam, one such seam increased in thickness from 2.45 ft to 2.96 ft within three months.

In the more arenaceous of the Upper Ordovician sediments, two equally prominent sets of joints have been developed. One set, normal to the axial planes of the folds, appear to be *ac* joints, and are concentrated near the fold axes. Less common, but still important are *hol* joints, with strike parallel to the fold axes, but cutting the axial planes at angles of from 30° to 90° . Least well developed are *hkl* joints. These are generally steeply dipping. The pattern is shown on Fig. 10a. To what extent these joints were due to folding, or to later deformations, is uncertain, since the pattern corresponds closely with that found in much younger rocks in the area.

Too few joints were mapped in the schists for statistical treatment to be attempted. Both *ac* and *hol* joints were recognized, the latter tending to be more frequent than the former. Dominating both were *hkl* joints, the result of shearing. These joints were invariably strongly slickensided.

Jointing is exceptionally strong in the permeation gneiss. At most exposures,

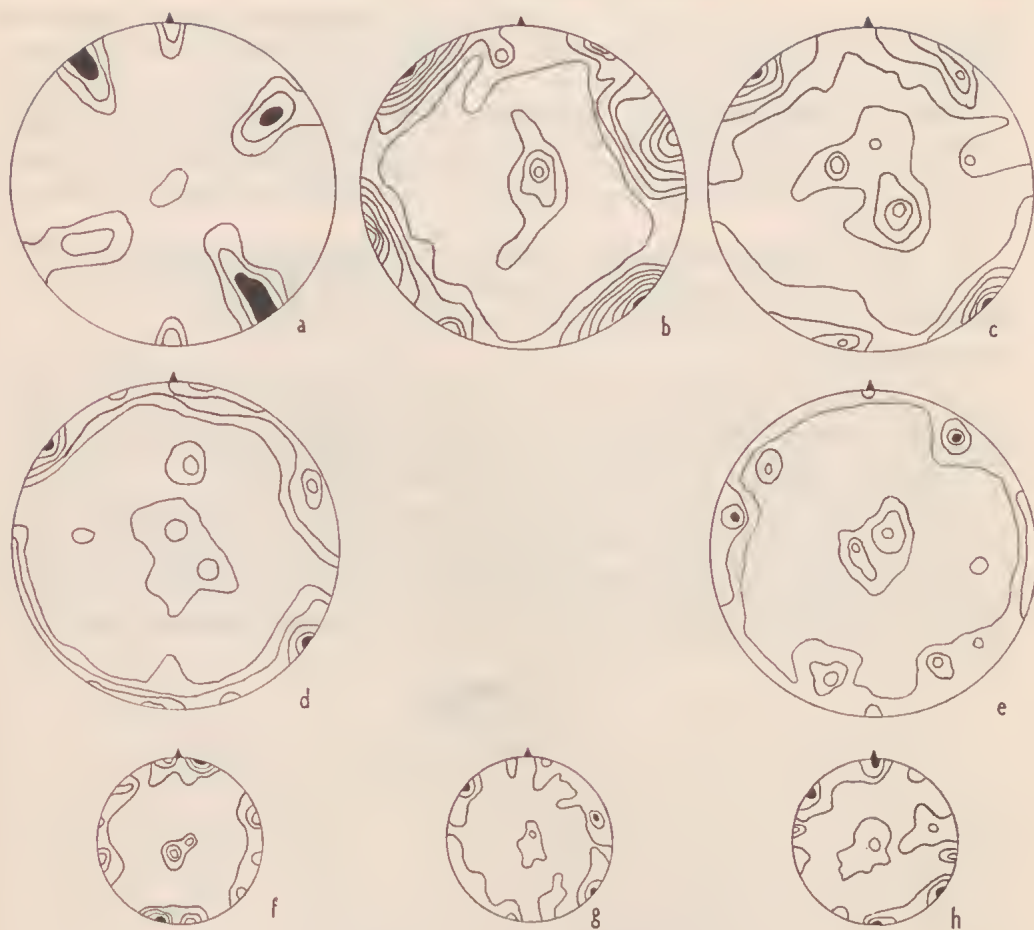


FIG. 10—Joint Patterns in the Kiewa Area.

- a. Poles to 75 joints, Upper Ordovician Sediments. Contours 6-3-1%.
- b. Poles to 1513 joints in permeation gneiss. Contours 8-7-6-5-4-3-2-1%.
- c. Poles to 1262 joints, Granodiorite. Contours 9-5-4-3-2-1%.
- d. Poles to 2871 joints in the area. Contours 5-4-3-2-1%.
- e. Poles to 106 joints, gneissic granodiorite. Contours 4-3-2-1%.
- f. Poles to joints in sub area 1A of Fig. 6. Contours 5-4-2-1%.
- g. Poles to joints in sub areas 2A and 2B. Contours 5-3-1%.
- h. Poles to joints in sub area 4A, 4B, 4C. Contours 5-3-1%.

three sets occur: one set has N.-easterly strike with vertical dip, the second N.-westerly strike with dip 70° to 80° SW., while the third set is flat. This system is clearly shown for the whole of the gneiss in Fig. 10b; the figure emphasizes the dominance of the first set.

Two main sets of joints intersecting at 60° are dominant in the granodiorites (Fig. 10c), while a third set, striking WNW., and with vertical dip, is less strong. One of the main sets coincides with the strongest set of the permeation gneiss. Again, flat joints are important. There is evidence of several ages of jointing in the

granodiorites (Pl. XLI, fig. 1). At Fall's Cr., lamprophyre dykes have been intruded along joints, while later joints cut both the lamprophyre and the granodiorite.

Jointing of the lamprophyres appeared generally to be the result of shearing. Usually, two sets, intersecting at 60° were present. Exposures of the quartz diorite were too poor for detailed study of jointing. One set, N. 70° E. is strong, and these may have been primary, since they are parallel to the flow structure in the upper levels of the mass.

The regional pattern of jointing for the area as a whole requires little comment at this stage. NE. striking joints are dominant (Fig. 10d). Marked variations occur from place to place; these variations are discussed later in the paper.

DYKE INTRUSION

The swarms of intermediate to basic lamprophyres, basalt, dolerite and phonolite dykes which occur throughout the area are only part of much larger swarms distributed throughout E. Victoria. One of the most notable features of the Kiewa swarm is the persistence of the almost E.-W. strike (Fig. 11a).

The thickness of the dykes is remarkably constant, 76% of those mapped having thickness less than 10 ft, while 50% have thickness between 1 and 5 ft. Only one dyke was mapped with thickness greater than 50 ft. Dip is usually vertical, and only rarely were dykes recorded with dip less than 60° . In the field, the constant association of dykes with the crush zones of faults was notable, the dykes occurring

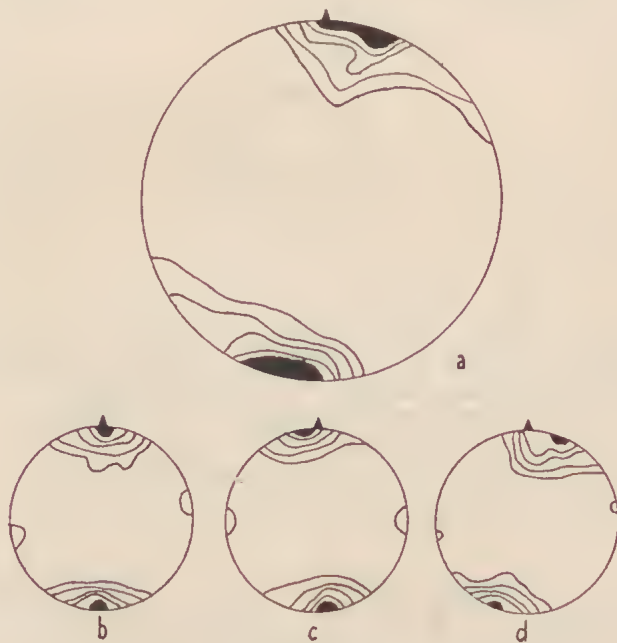


FIG. 11—Dyke Swarm at Kiewa.

- a. Poles to 863 dykes. Contours 8-4-3-2-1%.
- b. Poles to dykes, sub area 1A, Fig. 6. Contours 5-4-3-2-1%.
- c. Poles to dykes, sub areas 2A and 2B. Contours 5-4-3-2-1%.
- d. Poles to dykes, sub areas 4A, 4B, 4C. Contours 5-4-3-2-1%.

in groups of 3 or 4 on the walls of the crush zones. There are both local and regional departures from the statistical trend. E.g. there is a westerly swing of 20° in sub area 4, comparable to that noted for the fold axes; the areal trend also differs markedly from that for E. Victoria as a whole. At Kiewa, both field and statistical evidence support that faults controlled dyke intrusion. Elsewhere in E. Victoria, other controls operated, as at Woods Point, where the dykes were intruded along the axial planes of the folds.

FIELD AND TECTONIC RELATIONSHIPS OF THE STRUCTURAL ELEMENTS

Theoretical aspects of folding, faulting, jointing and dyke intrusion have been summarized by Anderson (1954), Billings (1954), McKinstry (1953) and Moody and Hill (1956). These workers have concluded that planes of failure in rocks make angles of less than 45° with the direction of maximum compressive stress, with an average value of this angle 30° . Experimental studies by Doubree (1879), Bucher (1920), Mead (1920), Riedel (1929) and Cloos (1932), in conjunction with theoretical analyses, have formed the basis for the interpretation of structural mapping. The recent study of structure in the Beartooth Mountains, U.S.A., by Spencer (1959), which was based on experimental results, is of particular importance in the present work because of the similarity of that area to the Kiewa area.

Spencer found that dyke intrusion had occurred along pre-existing fractures. A comparison of fracture patterns and folds in granite gneiss showed no consistent relationship between the two, although in some instances, the joints made angles of 30° with the fold axes; these joints were interpreted as conjugate shears related to the folding. Some joints were parallel to the fold axes, and some normal to the axes. These were regarded as tension joints due to folding. The multiplicity of patterns of jointing and faulting throughout the area was regarded by Spencer as due to later deformation of small blocks which had uniform and simple patterns when first deformed. Superposition of patterns gave an overall simple pattern, which suggested that rotation had not taken place; if there had been rotation, a large number of trends would have been expected. In determining the mechanics of deformation, Spencer adopted the Mead model, and found close agreement.

In the study of the relationships at Kiewa, the first phase of the work was the study of relationships in small areas. Table 13 shows the regional trends of faults, dykes and joints throughout the area. The data presented on the table does not emphasize any obvious relationship between the trends, although there is a tendency for a concentration in the 90° - 110° range. This examination on a regional scale does not take into account such factors as the influence of major faults and of varying rock type, both of which have been seen to be significant.

The control of such factors can be considered, and their influence eliminated, by the careful selection of small sub areas for study. Those selected were 2A, 4A, 4B, and 4C of Fig. 6, with a more general study of areas 1, 2, and 4. The results of the analyses are shown in Fig. 12, and in Tables 14, 15, and 16.

TABLE 13
Regional Trends of Joints, Dykes and Faults

Structure	Main Trend	Subordinate Trends	
Faults	65°	90°	120°
Joints	40°	110°	155°
Dykes	100°		

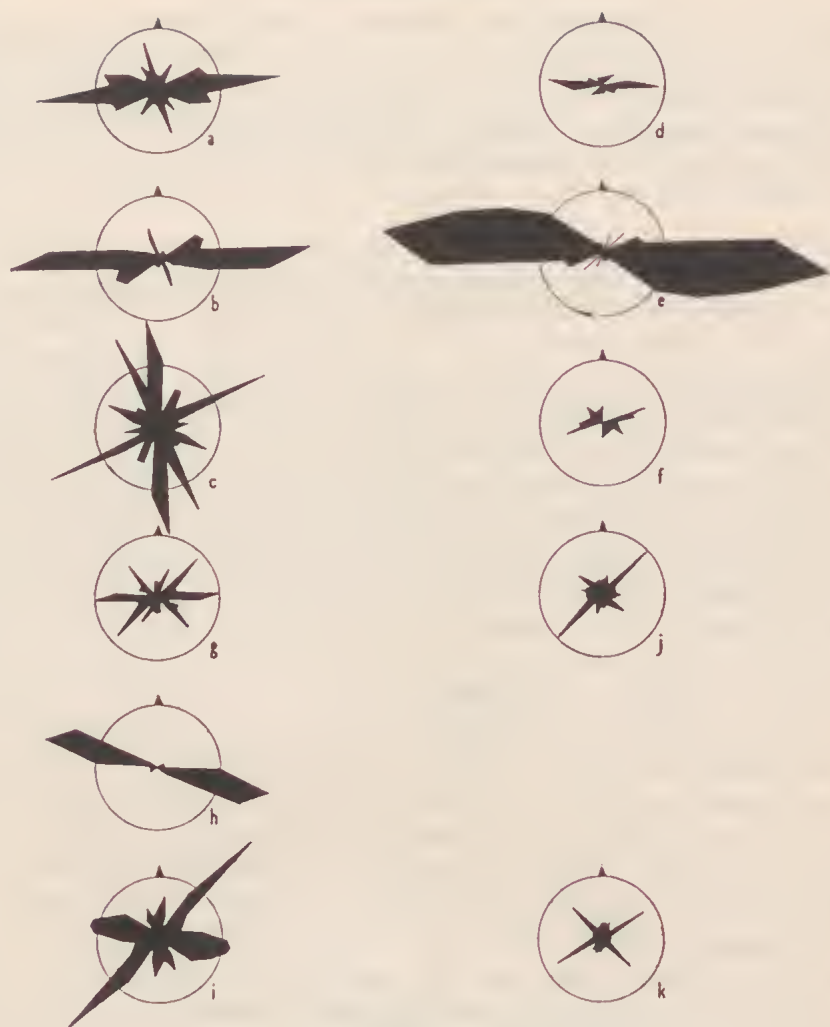


FIG. 12—Structural Trends in the Kiewa Area.

Radius of circle represents 10 structures.

- a. Faults in sub area 2A of Fig. 6.
- b. Dykes in sub area 2A.
- c. Joints in sub area 2A.
- d. Faults in sub area 4A.
- e. Dykes in sub area 4A.
- f. Joints in sub area 4A.
- g. Faults in sub area 4B.
- h. Dykes in sub area 4B.
- i. Joints in sub area 4B.
- j. Faults in sub area 4C.
- k. Joints in sub area 4C.

TABLE 14
Trends of Structures in Three Sub Areas

Sub area	Structure	Main Trend	Subordinate Trends
4	Faults Joints Dykes	90° 90° 110°	52° 135° 38°
2	Faults Joints Dykes	103° 162° 80°	75° 38°
1	Faults Joints Dykes	48° 105° 90°	74° 118° 165°

The No. 4 sub area shows the symmetry previously described. The main joint set is parallel to the main fault set, while one subordinate joint set is sub-parallel to a subordinate set of faults. The dykes are sub-parallel to the main sets of faults and joints. In the No. 2 sub area, there is no clear relationship, although the joint sets are more or less symmetrically disposed about the main fault trend, making angles of 56° and 65° with this trend. The lack of a statistical relationship between faults and dykes in this sub area was contrary to the conclusions reached in the field where the dykes and faults were intimately associated. In No. 1 sub area, again, no clear relationship was found: this led to the more detailed analysis which follows.

In the No. 4 sub area, three small sections, all in permeation gneiss, were selected: 4A, on the spur joining Mt Beauty and Big Hill; 4B, the No. 4 Underground Power Station area; 4C, near Mt Beauty Village, adjoining the Tawonga Fault. Some of the structures used in the general analysis of the No. 4 sub area were excluded from the detailed study because of the selection of these restricted sections. The results are shown on Table 15. Each of the small areas shows a close relationship between the trends of the several structural elements, although the dominant trends vary from place to place. In the 4A area, there is a single fault trend at 90°. Although the main joint set bears little relation to this, two of the subordinate joint sets do, one being parallel to the fault set, the other normal to it. Parallelism of the faults and dykes is emphasized. In the 4B area, the relationship between the patterns is even more obvious.

TABLE 15
Trends of Structures in No. 4 Sub Area

Area	Structure	Main Trends	Subordinate Trends
4A	Faults Joints Dykes	90° 70° 90°	90° 130° 0°
4B	Faults Joints Dykes	45° 95° 45° 105°	135° 25° 0° 100° 150° 0°
4C	Faults Joints Dykes	45° 50° 135° Data inadequate for analysis	15° 90° 135° 0° 45°

In the No. 2 sub area, two small sections were selected: 2A, on the Junction Spur, between Bogong and Howman Gap, in granodiorite; and 2B, on Spion Kopje, in permeation gneiss. The results are shown in Table 16.

TABLE 16
Trends of Structures in No. 2 Sub Area

Area	Structure	Main Trends	Subordinate Trends
2A	Faults	85°	30° 60° 105° 145° 160°
	Joints	175° 150° 60°	115° 95° 25°
	Dykes	95°	160°
2B	Faults	45°	20° 105° 145° 175°
	Joints	5° 90° 135°	30° 170°
	Dykes	Data inadequate for analysis	

Here, in spite of the multiplicity of patterns, the spatial relationships of the structures are clear.

The localized influence of major faults on the adjacent minor faults and joint patterns is seen, in these detailed studies, to be considerable, in contrast to other sectors previously described, where the influence of the major faults appeared to be insignificant. It is clear that the age relationships may have a considerable bearing on the spatial and tectonic relationships of the fracture structures; this aspect is considered below.

The relationship between joints and folds in the sedimentary and metamorphic rocks is not always clearly defined. The joint pattern of the sediments and schists is comparable to that for the whole area, regardless of lithology, and the question arises whether or not these joints may be of post folding age. It is more likely that joints were developed as a result of shear and tensile stresses during folding, the joints so formed receiving an emphasis during later deformations. In the permeation gneiss, statistical analyses show no relationship between the folding and jointing. In selected areas, however, the same relationship as that seen in the sediments, has been observed. On the No. 4 Head Race Tunnel line, two sets of joints make angles of 20° with the axial planes of the folds in the gneiss, while a third set is more or less normal to the axial planes.

In the gneissic granodiorite, one set of joints is parallel to the foliation, while a second set is almost normal to the foliation. The joint pattern of the gneissic granodiorite is unlike any other in the area, and it is probable that the shearing which produced the foliation resulted in the development of the joints.

From the detailed study of fracture patterns in the area, it is possible to develop ideas relating to the way in which the Kiewa area fits the general tectonic pattern of the East Australian Mobile Belt, as well as determining the detailed tectonic development of this small sector of the Belt. Hills (1947, 1955a, 1955b, 1956) has shown the importance of N.-easterly and S.-easterly structural trends in SE. Australia. The major trends at Kiewa, 60° and 160° fit this pattern while the other trends here, 45° and 90° are (approximate) bisectrices.

Assuming that the major diastrophisms of the Lower Palaeozoic were effective at Kiewa, and it has been shown that there is strong evidence for this assumption, an attempt has been made to relate structural trends in the area to each of these deformations. The orientation of the principal compressive stress for each orogeny has been assumed from the orientation of fold axes in sediments affected by the

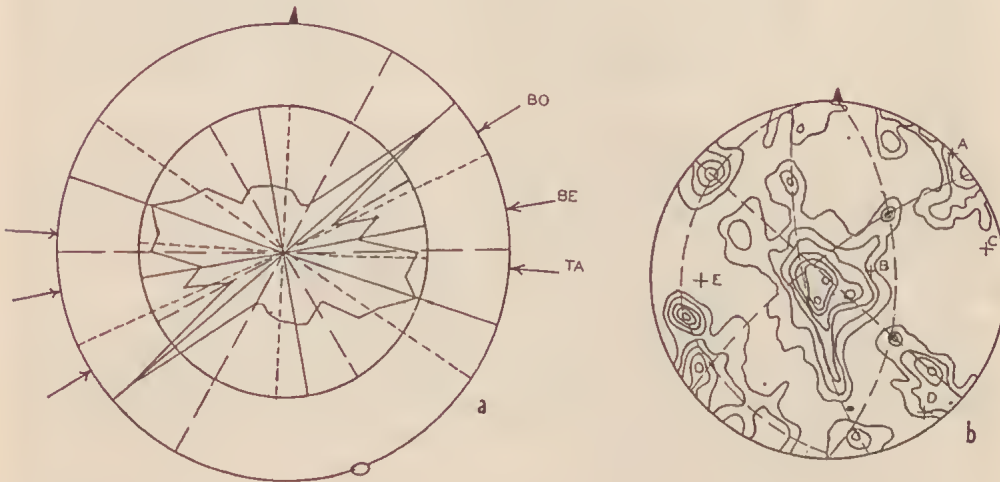
orogeny. Thus, for the Benambran Orogeny, the fold axes of the Upper Ordovician sediments, schists and gneisses strike N.15°W.; for the Bowning Orogeny, the Lower-Middle Silurian beds at Wombat Cr. have folds striking N.35°W.; the fold axes of the Middle Devonian beds at Buchan, folded during the Tabberabberan Orogeny (Teichert and Talent 1958) strike almost due N.

If the Spencer-Mead patterns are taken as a basis, and if it is assumed that each orogeny developed its own characteristic fracture pattern, the pattern for Kiewa would be as shown on Table 17.

TABLE 17
Theoretical Fracture Pattern

Tectonic Episode	Orientation of principal compressive stress	Fold Axes	Shears	Tension Fractures	Thrusts
Benambran	N.75°E.	N.15°W.	N.45°E. S.75°E.	N.75°E. S.15°E.	S.15°E.
Bowing	N.55°E.	S.35°E.	N.25°E. N.85°E.	N.55°E. S.35°E.	S.35°E.
Tabberabberan	W.-E.	N.-S.	N.60°E. S.60°E.	N.-S. E.-W.*	N.-S.
Kosciuskoan	S.45°E.	N.45°E.	S.15°E. S.75°E.	S.45°E. N.45°E.	N.45°E.

*Trend of basic lamprophyre dykes of Tabberabberan age.



Superposition of the actual fracture pattern on this assumed theoretical fracture pattern (Fig. 13) shows remarkable agreement between the two. This explanation of the fracture pattern at Kiewa depends on the validity of the basic assumptions that the three Palaeozoic orogenies were effective, that the pre-existing systems were modified only slightly or not at all by later deformations, and that each orogeny produced its own system of fractures. It should be noted that all of the fractures which could be produced by the Tertiary Kosciusko deformation, could also have been developed by earlier deformations.

Examining more closely the basic assumptions, there seems little doubt that the stresses associated with the Palaeozoic orogenies were effective at Kiewa, when strong direct evidence is available from all of the surrounding area. The assumptions that each stress application produced a new, independent fracture system, and that the earlier systems were little affected, are more difficult to consider, especially when there is clear evidence of rotation of at least one block. The former is reasonable, and finds support in the results of experimental deformation.

The validity of the assumptions, and to some degree, of the theory itself, can be tested by comparing the fracture patterns of the rocks affected. Thus the older sediments, schist and permeation gneiss should show the imprint of all the deformations; the grandodiorite of the Bowning, the Tabberabberan and Kosciusko; the quartz diorite, the Tabberabberan and Kosciusko; and the basalts, the Kosciusko only. Such testing is not simple since, as Table 17 shows, some trends are common to more than one deformation.

In the simplest cases, the basalts, only faults can be studied, since any tectonic joints are obscured by the primary jointing. All of the faults recorded occupy precisely, or in isolated cases, approximately, one of the four trends possible for the Kosciusko episode: N.45°E., E.75°E., E.45°E., and S.15°E. In the quartz diorite, too few measurements could be made for certain investigation, but the main trends recorded were N.-S., E.-W., N.45°E., N.60°E., S.60°E., and S.15°E. When the older rocks are examined, the multiplicity of patterns becomes evident, but there is a definite emphasis on the pattern which would have resulted from the Benambran Orogeny.

The two dimensional analysis of the fractures just described takes no account of the numerous flat lying structures mapped. For the analysis to be complete, such flat structures must be considered, since neglect of these could result in the failure to recognize some possibly important aspects of the tectonics. A three dimensional analysis would be expected to lead not only to the geographical orientation of the stresses, but also the inclination from the horizontal of these stresses.

For this analysis, conjugate pairs of fractures were plotted at projections on the Schmidt equal area net. The line of intersection of each pair of planes is then represented as a point on the projection. On completion of the plotting, the point diagram resulting, was contoured in the usual way. Fig. 13b was prepared in this way for 1256 points; plotting of a greater number of points was not practicable. Counting was with a $\frac{1}{2}\%$ counter.

The maxima of the diagram are seen to lie on five girdles, the poles of which represent the orientation of principal compressive stresses, as shown on Table 18.

The trend A is to be regarded as the orientation of the principal compressive stress of the Bowning Orogeny; B and C, the Benambran; D, the Kosciuscoan; and E, the Tabberabberan. As would be expected, the stresses are, with one exception, sub-tangential. The development of the near vertical stress B was probably associated with the late stages of Benambran activity.

TABLE 18

Pole	Trend	Plunge
A	N.42°E.	5°
B	N.72°E.	70°
C	N.77°E.	10°
D	S.38°E.	16°
E	E.-W.	25°

This analysis depends on the relationship between the principal compressive stress and the strain axes, based on theory discussed at length by Jaeger (1956) and Anderson (1951). The girdles containing the maxima lie in the plane defined by the least and intermediate principal stresses.

RESUME OF STRUCTURE AND THE RELATIONSHIP BETWEEN STRUCTURE AND IGNEOUS ACTIVITY

The general picture that has emerged from the study of folding at Kiewa is of a major anticline, the axis of which has a gentle northerly plunge, with local plunge to the S. The W. limb of this fold has been sheared through on the West Kiewa Thrust. Minor complexities occur, but overall the fold is a relatively simple structure. On a broader scale, it is possible to conceive of this structure as being a minor fold associated with the Geanticline, described by David, which developed in the East Australian Mobile Belt during the Benambran Orogeny.

Statistical geometry of the folds indicates only one period of folding, the Benambran, although the area has been subjected to at least four deformations. Erosion had proceeded to an advanced stage by the late Silurian, so that the rocks at present exposed, were at no great depth in the crust during the post Benambran deformations. The condition of the rocks under such conditions would be brittle rather than plastic, and any strain would be represented by fracture rather than flexure.

The fractures are the most important structural elements in the area. Examination of detailed geological maps of SE. Australia suggests that the Eastern Highland belt is somewhat unique (cf. Hills 1956) in the intensity of fracturing. This leads to the consideration of the Eastern Highlands as a great crush zone. As suggested by Hills (1956) and confirmed for the Kiewa area at least by the present work, many of the faults are high angle thrusts. Several important wrench faults have been recorded, but normal faults are rare. Four trends are outstanding: N.-easterly, easterly, S.-easterly, and N.-S. These trends are important throughout the Eastern Highlands, and conform to the network of Vening Meinesz (1947).

The N.-easterly trend is particularly significant since faults with this trend tend to form the W. boundary of the Highlands. Although faults with this trend are among the oldest, Tertiary faulting, including renewed movement on older structures, follows this direction. The late uplift of the Highlands is indubitably the result of these movements. The late movements are expressed by a gentle fault controlled warping, giving rise to a broad, faulted anticlinal structure, with a N.-easterly trending axis. During the Benambran Orogeny, the only certain manifestation of igneous activity was migmatization, accompanied by granatic pegmatites. The relationship between folding, metamorphism and migmatization was close, and all three are to be regarded as occurring contemporaneously. The migmatite is completely concordant with sedimentary structures present in the

permeation gneiss. At Kiewa certainly, and probably in other areas which were examined cursorily in the present work (e.g. Dartmouth, in the Mitta Mitta valley), the migmatites are restricted to the cores of major anticlines.

The migmatization possibly slightly pre-dated the West Kiewa Thrust, which forms the W. boundary of the migmatite at Kiewa. The thrust, however, exerted a major control on later intrusions. The granodiorites probably represent the stage of late tectonic intrusion of the Bowning Orogeny, extending into the post tectonic stage. The two main masses, the Niggerheads and the East Kiewa, as well as the Pretty Valley gneissic granodiorite, crudely elliptical in shape, have long axes parallel to the structural grain of the country, and, in a sense, are concordant, although when closely examined, are discordant, at least locally. The major axes of these intrusions are coincident with one of the tension (relaxation) directions of the Bowning Orogeny, and it is likely that both the intrusion and the shape of the intrusive masses was controlled by this factor.

The proximity to, and the elongation along, the West Kiewa Thrust of both the Niggerheads granodiorite and the gneissic granodiorite of the Cobungra R., suggest that the Thrust may have exerted some control over intrusion and, in fact, may have provided ready access for the magma. On the other hand, if this were the case, more intense intrusion of the crush zone of the thrust itself would be expected.

The intrusion of the quartz diorite was almost certainly controlled by post tectonic relaxation associated with the Tabberabberan Orogeny, while the intrusion of the lamprophyre dykes occurred more or less at the same time along tension cracks and 'openings' in crush zones. The almost exclusive E.-W. orientation of the dykes supports this view.

The extrusion of the basalts was associated with the development of tension in the early stages of the Kosciuscoan movements. The main centres of eruption at Kiewa fall on a line coincident with a tension trend for this deformation.

Three more general relationships between igneous activity and structure may be considered. The first of these is the influence of the West Kiewa Thrust on the distribution of intrusive masses. It can be seen in Fig. 1 that the area immediately E. of the Thrust is marked by a large number of small intrusive masses; such masses are absent W. of the Thrust. One of the more obvious conclusions is that the movement on the Thrust, with upthrow to the E., and therefore accelerated denudation, has led to the exposure of these masses. An alternative is that the mylonite zones of the Thrust formed a barrier against the magma, but the reverse would in fact be expected, i.e. that the crush zone would facilitate magma migration.

The former hypothesis is the more attractive. Movement on the Thrust is unknown, but almost certainly it would have been of the order of tens of thousands of feet. In addition, movement occurred during several periods, and for the hypothesis to be tenable, one such movement, post dating the Tabberabberan intrusion of the quartz diorite, would be necessary. No definite evidence for this is available. The evidence of the near roof schlieren and other flow phenomena at Big Hill suggests that the exposure is close to the original roof. It is possible that other masses occur W. of the Thrust, but are not yet exposed. The evidence for this is slender, and reference can be made only to the general low grade metamorphism shown by some of the Upper Ordovician sediments W. of the Thrust.

The second general relationship to be considered is that of the intrusive masses to structure. Thom (1955) has discussed wedge uplifts, taking as an example, the Beartooth Mountains, U.S.A. These wedge uplifts are essentially coincident in size and outline with granitic batholiths, which have 'headed' as they approached the

surface thus giving, on cooling, massifs with the shape of downward pointing wedges. Although such structures were considered, there is no evidence for their development at Kiewa. It is important to note, however, that most of the sub-meridional boundaries of the intrusive masses are faulted, with the faults almost invariably high angle thrusts. Besides these, there are a number of others which together impose on the area a type of imbricate structure. That the igneous boundaries are so frequently faulted is due less to chance than to the structural weakness of the normal contacts, and to the original orientation of the contacts in a direction parallel to shear directions of post intrusive deformations.

Finally, the structural relationships of the dyke swarms may be considered. It has been shown that the dykes at Kiewa have a consistent E.-W. trend, and this has been related to tensile relaxation of the Tabberabberan orogeny. In considering the structural relations of the swarm as a whole it must be remembered that dykes of varying petrographic type, and of varying age are represented. Additionally, rocks with markedly different structure are hosts to the dykes. In the Palaeozoic sedimentary belts, the dykes have trend parallel to the fold axes (Woods Point, Ovens Valley, Bendigo). The dykes of South Gippsland which intrude Jurassic sediments are generally normal to the monoclinial axes.

In North East Benambra, the dykes are intrusive into igneous and metamorphic rocks, the structure of which is virtually unknown. These dykes have a trend normal to those at Kiewa, with the exception of one group which strikes N.-easterly, parallel to an important shear direction in this region. Dyke intrusion appears to have been controlled by both host rock structure, and stress conditions during intrusion.

STRUCTURAL CONTROL OF TOPOGRAPHY IN THE KIEWA AREA

Within the Kiewa area, the summits of all the more important peaks are at elevations of more than 6,000 ft, some hundreds of feet above the general level of the Bogong High Plains. The gently undulating topography of the High Plains, in strong contrast to the surrounding, deeply dissected areas, is found not only on the High Plains proper, but also on the divides between the various branches of the Kiewa R., and between these and the Mitta Mitta and Ovens R. This suggests a former continuity of this mature, gentle terrain. One of the more important features of the mountains is the accordance of summit levels, as shown on Table 19.

TABLE 19
Peak Accordance: Kiewa

Mountain	Elevation (ft)	Mountain	Elevation (ft)
Fainter North	6120	Nelse North	6273
Fainter South	6249	Spion Kopje	6117
Niggerheads	6150	Arthur	5575
Loch	6244	Bogong Central	6527
Hotham	6193	Little Bogong	5558
Jim	6008	Feathertop	6398
Cope	6116	McKay	6137
Nelse	6257	Little Spion Kopje	5278
Bundarra	5745	Bogong	6601

Note: Elevations are those of detailed topographic maps used and are based on S.E.C. false datum 92 ft above M.S.L.

A series of broad, mature, alluviated valleys, ranging in elevation from 5,300 ft (Rocky Valley) to 5,800 ft (Big R.), occur on the Bogong High Plains, and from these, gentle divides rise to elevation 5,800 ft in the S. and 6,300 ft. in the N.

To the NW. of the Tawonga Fault, there is a marked change in the topography. The average elevation of the divides is 4,000 ft, with the terrain at the stage of early maturity. The uplift to the SE. of the Tawonga Fault has resulted in rejuvenation of drainage of the uplifted block, and the Bogong High Plains are a remnant, as yet unaffected by headward erosion, of the pre-uplift terrain. If the High Plains are thus regarded, a new approach can be made in assessing the factors responsible for the maturity of the high plains valleys.

Kenny (1937) explained the valleys by postulating blockage by the Older Basalts, with lake formation. This is unacceptable since there is no doubt that the present stream system post dates the Older Basalts. Crohn (1949) postulated reduction in grade of the streams due to a S.-easterly tilt which accompanied the uplift on the Tawonga Fault, and cited as evidence the 'lack' of alluviated valleys on the SE. margins of the plains. Such valleys, however, do occur on the S.-easterly margin, notably Jack Cr. Carr and Costin (1955) attempted to explain Rocky Valley by the blockage of the stream with Pleistocene moraine at Langford's Gap. This has been shown (Beavis 1959) not to be tenable since no moraine occurs on the Bogong High Plains. It is considered that the alluviated valleys are merely remnants of the pre-uplift valleys, evidence of which can be traced downstream from the high plains in the valley in valley structures.



FIG. 14—Tertiary Warping in Eastern Victoria.

If the mountain and high plains areas of E. Victoria are considered on a broader scale, it can be seen that there is a basic structural control of the topography. On the broadest scale, warping on a NE.-SW. axis is apparent. If the elevations of all the mountains are plotted (Fig. 14) and contours constructed, the distinct warp can be clearly seen with the axis passing through Cobbler and Mt Bogong to Mt Kosciusco in N.S.W.

The E. margin of the warp is broken by the Tawonga Fault, and possibly by other young faults parallel to this. The warping and faulting were contemporaneous and, in fact, the warping is to be regarded as an expression of fault movement. Thus,

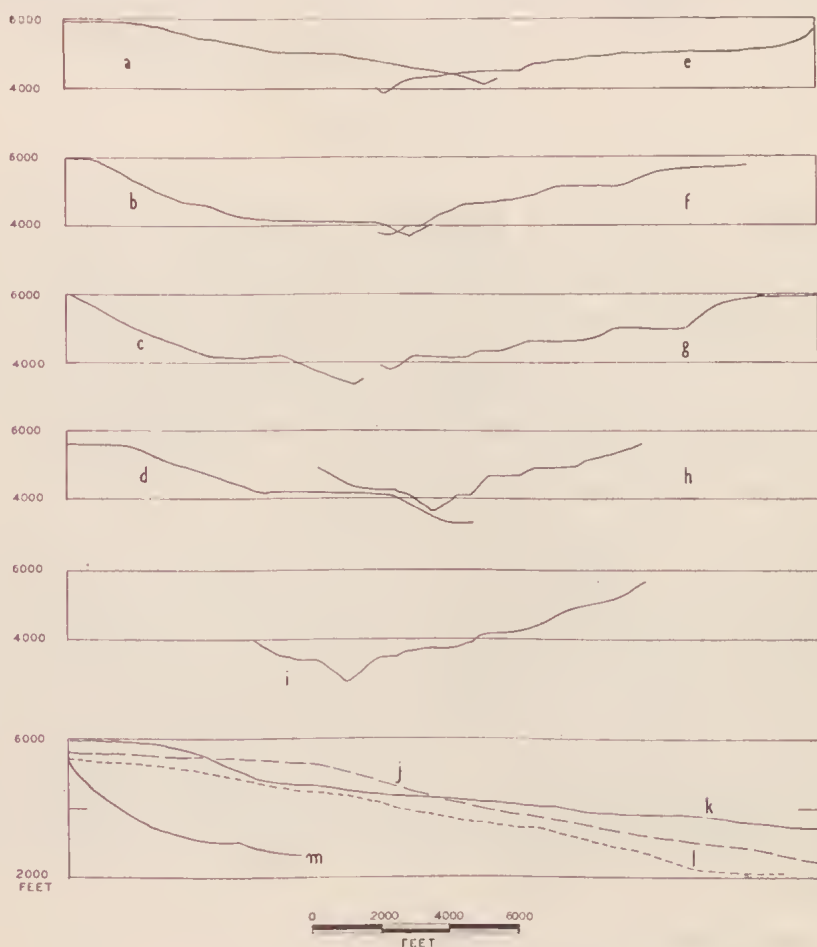


FIG.15—Valley Cross Sections and Stream Gradients, Kiewa.

- a.-h. Cross sections of Big R. valley.
- i. Cross section, East Kiewa R. valley.
- j. Stream gradient, Pretty Valley.
- k. Stream gradient, Big R.
- l. Stream gradient, Rocky Valley.
- m. Stream gradient, Spion Kopje Cr.

on the W. margin of the warp in the Kiewa area, we have going from E. to W., the Sassafrass Creek Fault and minor parallel faults, the Tawonga Fault, the Bright Gap Fault, and the Running Creek Fault, all with upthrow to the SE. On the E. side, little work has been done, but it is probable that faults with upthrow to the NW. occur, comparable to the Livingstone Creek Fault described by Crohn (1949).

Continuation of the axis of warping to the SW. shows that many of the elevated plateaux such as the Dargo High Plains and the Baw Baws fall on the axis. Thus the mountain belt of E. Victoria may be ascribed to this Tertiary fault-warping. It follows that the stream development would be modified by the warping and, while on a local scale, faulting alone seems to have acted as control, on a regional scale the warping has been the dominant factor. This concept agrees in part with Crohn's idea of tilting to the SE., but with the warp axis passing through the Bogong High Plains, tilting to the NW., not recognized by Crohn, also occurred.

THE DEVELOPMENT OF THE STREAM SYSTEM

MITTA MITTA RIVER—

The main tributaries of the Mitta Mitta R. which have their sources on the Bogong High Plains are Big R., Middle Cr., and the Cobungra and Bundarra R. Big R. has its source on the W. slopes of Mt Nelse and the N. slopes of Spion Kopje; the headwaters are mature, with alluviated valleys, and stream gradient 1: 250. Initially, the stream flows westerly, but near the knick point, separated from Spion Kopje Cr. by a low saddle, elevation 5,750 ft, the stream turns sharply to the N. The elevation of the knick point is 5,800 ft. The northerly trend is maintained to elevation 4,150 ft, where the stream turns sharply W., with a low saddle, 4,600 ft separating the Big R. from Bogong Cr. It is obvious that both of the low saddles mentioned were formerly occupied by streams and that, Big R. has captured the headwaters of both Spion Kopje and Bogong Cr.

The valley of Big R. is markedly asymmetric (Fig. 15) a feature typical of all the valleys in the area. The slope of the S. wall averages 1: 3·5, while that of the N. wall averages 1: 5·5. There is a sharp flattening of the spurs at elevations 4,200-4,000 ft, 5,000 ft, and 5,800 ft. The floor of the valley is locally strongly alluviated, long narrow alluvial flats occurring on alternating sides of the streams downstream from elevation 4,150 ft (in the stream bed). Much of this alluvium has had its origin in landslide debris; large landslips are a feature of the valley walls. In one section between the source and the foot of T Spur, development of the stream on the crush zones of faults has been proved, and it is a reasonable assumption that the rectangular pattern of the streams throughout this catchment is due to the same control. Locally, as near the junction of Cairn Cr. with Big R., the main stream has left, for no apparent reason, a strong crush zone. Whether or not activity on faults so late in the history of the area has been responsible for this is a matter for conjecture.

KIEWA RIVER—

The two main branches of the Kiewa R.—the West Kiewa and the East Kiewa—have their junction immediately downstream from Mt Beauty village. The junction of the two main branches of the East Kiewa R.—Pretty Valley and Rocky Valley—is at Bogong village. Because of the complete lack of contoured maps of the West Kiewa valley, all physiographic studies of this valley were purely qualitative.

The West Kiewa valley is strongly asymmetric, with the steeper slopes on the E. side. Locally, as on the flanks of Mt Fainter, the valley is gorge like, with near vertical walls up to 600 ft high. Dissection on this valley is far more advanced than that observed in other catchments in the area, while the alluviated headwaters, typical of the East Kiewa and Big R., are absent. The Cobungra Gap between the West Kiewa and Cobungra R. is indicative of capture of the West Kiewa headwaters by the Cobungra. Stream gradient averages 1:20 over almost the full length of the stream, but is steeper in the headwater tributaries. Small alluvial flats are found in the valley floor for the entire length, and, downstream from Young's Gap, these increase in size. The flat at the junction of the West Kiewa and Diamantina is of some interest since it is traversed by a depression, obviously an extremely recent course of the West Kiewa, some 20 ft lower than the present bed. The most probable explanation of this is diversion of the stream by miners who worked this area in the latter half of the last century.

The structural control of this valley is obvious: the valley follows, for the greater part of its length, the mylonite belt of the West Kiewa Thrust, and where the valley leaves this belt, it is on a younger, almost E.-W. structure.

The two main branches of the East Kiewa R. have their sources on the Bogong High Plains. The headwater sections have mature, alluviated valleys, with stream gradients 1:250. At the knick points the gradient increases to 1:15. The cross sections of the valleys are asymmetric, with steeper slopes on the E. sides. Flattening of spurs, producing valley in valley structure, is present at elevations 5,000, 4,000 and 3,600 ft. Field study, supplemented by the air photo interpretations, shows a contrast in the stage of development of Pretty Valley with that of Rocky Valley. The latter is more juvenile than the former, particularly downstream from Howman's Gap. Upstream from this gap, both streams have gradient 1:16, but downstream, Rocky Valley has gradient 1:10, while Pretty Valley gradient is 1:16 to 1:20. Slope of the walls of Pretty Valley average 1:3, whilst those of Rocky Valley have slope of 1:1.5 to 1:2.

There is strong evidence that Rocky Valley formerly flowed through Howman's Gap, along the present course of Sassafrass Cr., and had its junction with Pretty Valley just downstream from the Pretty Valley-McKay Cr. junction. Alluvium is found faulted to depths of 110 ft along Sassafrass Cr. Nelse Cr. may formerly have been the main stream, with upper Rocky Valley tributary to it, an idea supported by the generally deeper dissection of this valley than in Rocky Valley. Capture of the main streams by what is now the lower section of Rocky Valley occurred as a result of recent movement on the Sassafrass Creek fault, supplemented by the general warping. Similar capture has occurred near the junction of Spion Kopje Cr. with Rocky Valley.

Below the junction of the two branches, the East Kiewa flows in a youthful valley, with gradient 1:20, until it crosses the Tawonga Fault, where it reaches grade. As with other streams in the area, the structure has controlled the pattern of this stream. This is particularly so between Junction Dam and Clover Dam where the stream follows the faulted gneiss-granodiorite boundary.

Spion Kopje Cr. is one of the most important tributaries of the East Kiewa. For almost its entire length it occupies the crush zone of the Spion Kopje Fault, leaving this $\frac{1}{2}$ mile upstream from the junction with Rocky Valley, where capture took place. All of the tributaries of this stream have developed on the minor faults of the Spion Kopje system. The stream has a steep gradient ranging between 1:5 and 1:1. The valley walls are steep, with slopes between 1:0.8 and 1:2.

STRUCTURAL CONTROL OF THE DRAINAGE PATTERN

Although structural control of the drainage pattern is generally indisputable, one catchment, Rocky Valley, was selected for detailed analysis. Attempts to correlate stream and fracture trends showed no clear relationship; however, analysis of variation of trends from E.-W. showed a clear relationship (Table 20).

TABLE 20
Correlation of Stream Trends and Fault Trends

Degrees from E.-W.	x	Faults	Streams	Faults/ Stream y
5	1	25	34	0.74
15	3	15	30	0.50
25	5	12	23	0.52
35	7	4	15	0.27
45	9	3	12	0.25
55	11	8	22	0.36
65	13	4	17	0.25
75	15	4	30	0.13
85	17	9	37	0.24

Correlation coefficient $r_{xy} = 0.8$.

In this catchment, faults appear to have influenced the development of streams with an E.-W. trend more than that of streams with other trends. When this technique was applied to the whole of the area, no statistical correlation was found, so that the tentative conclusion reached for Rocky Valley is not generally applicable, a finding already established in the field.

As stated earlier, the general fault warping has exerted a considerable influence on the streams. On the SE. of the axis, capture has been by E.-flowing streams, and on the NW. side of the axis, by W.-flowing streams. Capture in both cases was due to increase in stream gradient with the warping. This is clear evidence that the fault movements, responsible for the warping, have continued late in the history of the area.

The relationship between structure and drainage pattern in the Kiewa area is a restricted example of the more general relationship which exists throughout NE. Victoria (Thomas 1949, Hills 1955b). Crohn ascribed the captures in the region to an earlier cycle of erosion, and concluded that the stream pattern was antecedent to the recent tectonic movements. It is true that the streams have generally developed on ancient faults, but the captures have clearly taken place during the present cycle. The movements of the warping began about the time of extrusion of the Older Basalts, and periods of still stand, indicated by the flattening of spurs at elevations 6,000; 5,800; 5,000; 4,200; and 3,600 ft, were frequent. With these repeated interruptions to the cycle, the physiographic development of the area would be expected to show considerable complexity, and there is no simple explanation for all of the features observed.

STRUCTURE AND ECONOMIC GEOLOGY

Very few ore bodies have been recorded in the Kiewa area. Gold mines have operated at Hotham Heights (Kenny 1941), Tawonga (Beavis 1949), and Glen Wills (Crohn 1958). Crohn reported torbenite from Glen Wills, while small

crystals of this mineral were found by tunnelers in the alluvium of the Kiewa R. Although tantalite found by the author on Mt Bogong was associated with a pegmatite dyke, all other ore bodies in the area are associated with faults.

During the present work, the main economic interest was in the influence of geology in the design and construction of the Kiewa Hydroelectric Project. Although a vast amount of work was done in this field it is possible here only to summarize the main findings.

JOINTS

In engineering excavations, the majority of groundwater discharges occurred along joints. Some discharges were associated with the crush zones of faults, but these were comparatively rare. A certain selectivity was noted, only some joints discharging groundwater; these were not restricted to any one set. The numerous shafts sunk in the area provided ideal conditions for the study of groundwater flow in jointed rocks, and the results suggested that flow under these conditions was similar to that through a porous medium, the joints having, *en masse*, the role of pores.

Leakage from unlined pressure tunnels, and around and beneath dams was restricted mainly to joints. Joints, however, were important more in the way they controlled stability of excavations. Portal works for the No. 4 Head Race Tunnel involved benching on the nose of a spur in jointed gneiss. The excavation affected the stability conditions of the spur, and there was a tendency to failure by sliding along joint planes. At Clover Dam, on the W. abutment, the sheeting tended to control the stability of the slopes with respect to sliding, and movement along sheeting tended to induce sliding along tectonic joints. At No. 4 Underground Power Station, the long axis of the station was parallel to one set of major tectonic joints. During construction, one wall of the station failed along one of the joints. At depth, the tectonic joints were generally 'tight', but they normally opened as an expression of the redistribution of stresses which followed excavation.

FAULTS

In engineering construction, the significance of faults depended on the width of the crush zone, the material comprising the crush zone, and the attitude of the faults in relation to the excavation. Crush zones of gouge and breccia were responsible for difficult excavation, whilst mylonites created no problems of any magnitude. The importance of orientation of the faults is illustrated by the 6 inch fault which formed one wall of the upstream section of the No. 4 Tail Race Tunnel, and traversed the pillars between the draft tubes of the power station. This fault was responsible for failure both of the wall of the tunnel and of the pillars. Worst conditions existed when the faults were parallel to the long axis of the excavation.

Faults were frequently met in dam foundations. These had inferior foundation properties, and special design was required. At the site of the No. 1 Underground Power Station the soil developed on a very wide crush zone proved to be very unstable with respect to sliding, and it was impossible to construct permanent structures on the zone. No faults are known to be active in the Kiewa area, but it is not improbable that movement could occur on some of the younger structures.

The intimate association of the lamprophyre dykes with faults led to engineers regarding the dykes as troublesome. In fact, with the rare exception of rapidly weathering dykes, these structures, in themselves, created no problems in construction, unless they were sheared. Where the dykes were deeply weathered,

excavation down to fresh rock was often desirable, but unless the dykes were thick, this excavation was not carried out.

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Explanation of Plates

PLATE XXXIX (Ordinary Light)

- Fig. 1—Knotted schist, Mt Bogong.
- Fig. 2—Knotted schist, Mt Nelse.
- Fig. 3—Low grade schist, Cobungra Gap.
- Fig. 4—Permeation gneiss at contact with granodiorite, Spion Kopje.
- Fig. 5—Gneissic granodiorite, Pretty Valley.
- Fig. 6—Andalusite rock, contact of knotted schist with granodiorite, Mt Nelse.

PLATE XL

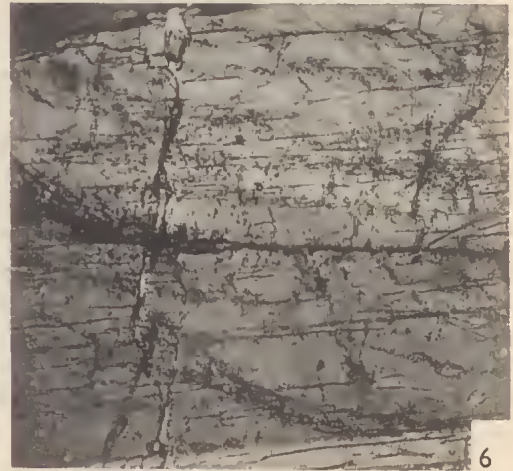
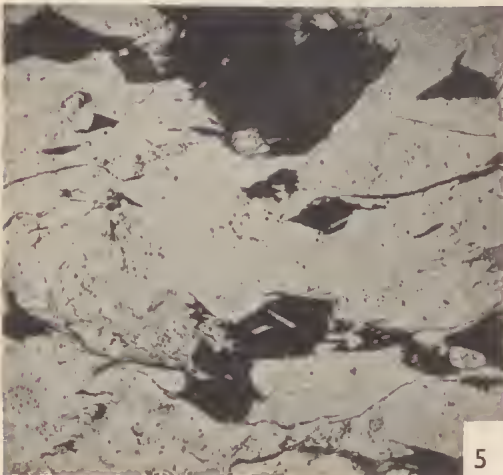
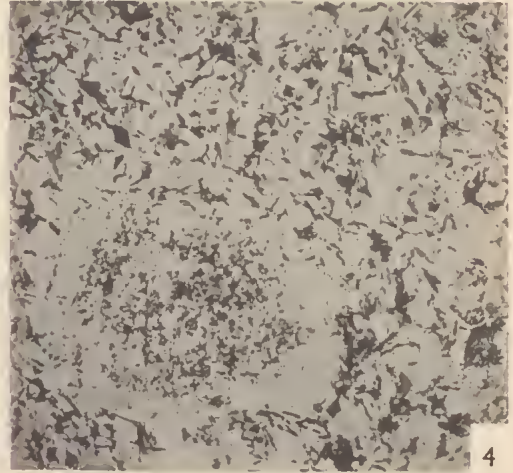
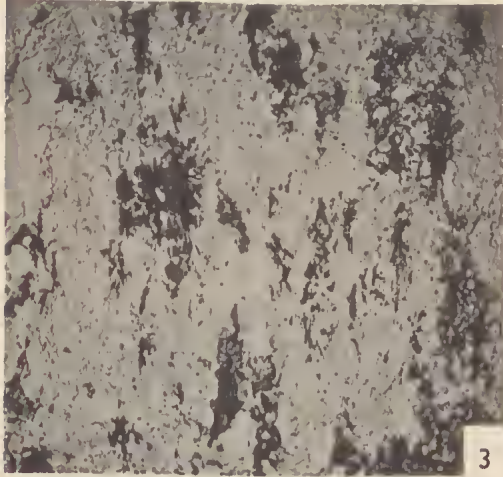
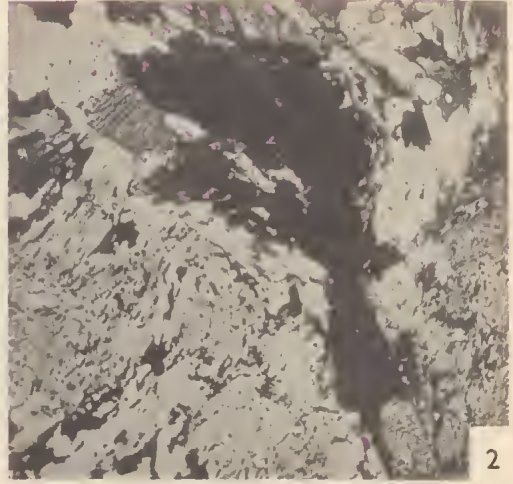
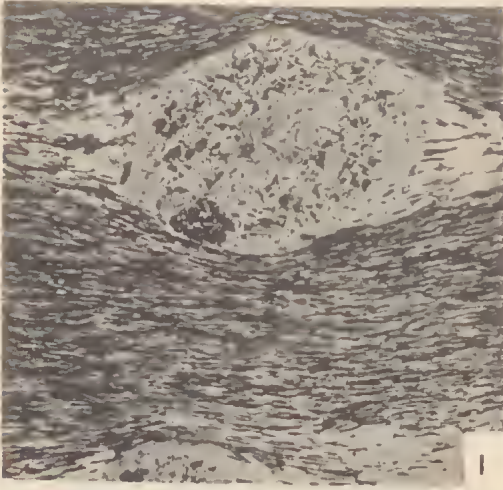
- Fig. 1—Lcaf beds, Bundarra R.
- Fig. 2—Basalt at Basalt Hill.
- Fig. 3—Exposure of Bogong Fault, East Kiewa R.
- Fig. 4—Fold in schist, Mt Nclse.
- Fig. 5—Shear in Upper Ordovician sediments near West Kiewa Thrust, Mt Hotham.

PLATE XLI

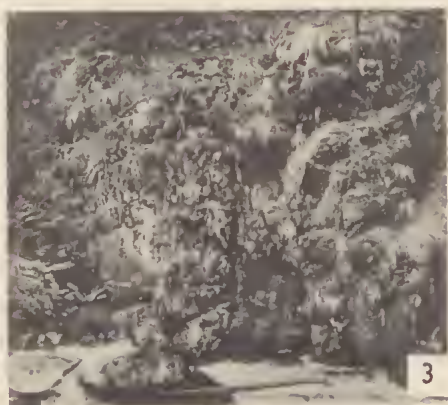
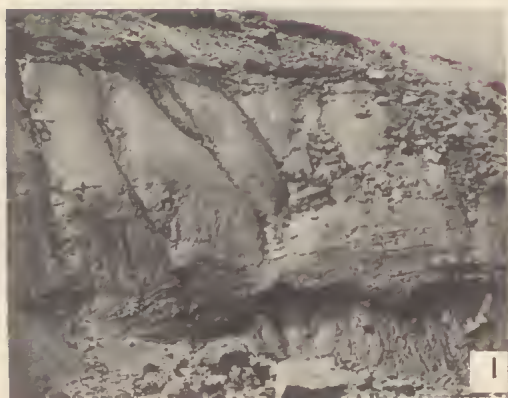
- Fig. 1—Lamprophyre dykes intruded along joints in granodiorite, with later joints traversing both rocks, Falls Cr.
Fig. 2—Lamprophyre dykes intruded along joint in granodiorite, Rocky Valley Dam.
Fig. 3—Flat shear in granodiorite, Windy Gap.
Fig. 4—Weathering on joints in granodiorite, Rocky Valley.

PLATE XLII

- Fig. 1—Strike ridges in Upper Ordovician sediments, with Mt Buffalo in distance.
Fig. 2—The basalts of the Bogong High Plains, from Niggerheads.
Fig. 3—Spion Kopje Cr., developed on Spion Kopje Fault.
Fig. 4—A typical High Plains valley—Pretty Valley, looking towards the knick point.



1 MM







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Neboiss, A., MSc, National Museum of Victoria, Russell St, Melbourne, C1	1957
Newnham, I. E., MBE, MSc, Chemical Research Lab., C.S.I.R.O., Box 4331, GPO, Melb., C1	1961
Nielsen, Miss B. J., MSc, 45 Summerhill Rd, Glen Iris, SE6	1954
Nye, E. E., BSc, College of Pharmacy, 38 Royal Pde, Parkville, N2	1932
Olsen, C. O., BA DipEd, Federation Military College, Port Dickson, Malaya	1945
Orr, R. G., MA BCh, 9 Heyington Pl., Toorak, SE2	1935
Osborne, A. G. A., BAgSc, 'Lowestoft', Warrandyte	1957
Osborne, N. A., 1 Matong Rd, Mt Eliza	1930
Owen, W. R., MSc PhD, ARACI, Victorian College of Pharmacy, 381 Royal Pde, Parkville, N2	1962
Paine, D. W. M., BSc For, 17 Loddon St, Box Hill, E11	1961
Parker, C. D., BSc DipBact Lond., FRACS, 47 Outlook Dr., Eaglemont, N22	1957
Parry, R. H. G., BCE MEdSc PhD, C.S.I.R.O. Soil Mechanics Section, Coleman Pd., Syndal	1959
Perdrix, J. L., 43 William St, Box Hill, E11	1961
Pescott, R. T. M., MAgSc, FRES MIBiol, Royal Botanic Gardens, S. Yarra, SE1 ..	1944
Peterson, G. T., PhC FPS, 'Carinya', E. Boundary Rd, E. Bentleigh, SE15	1958
Philip, G. M., MSc, Geology Dept, Univ. of New England, Armidale, 5N, N.S.W. ..	1955
Potter, Sir W. Ian, BEe, 30 Sargood St, Toorak, SE2	1957
Preston, H. E., 47 Haig St, Box Hill, SE11	1949
Purnell, Miss H. M., MSc, Botany Dept, University, Parkville, N2	1957
Purnell, W. E., FRACI, 30 Currajong Av., Camberwell, E6	1960
Rade, J., MSc, Flat 28A, 601 St Kilda Rd, Melbourne, SC2	1961
Radford, W. C., MBE, MA MEd PhD, 236 Belmore Rd, Balwyn, E8	1958
Rayner, J. M., BSc, FInstP, 5 Tennyson Cr., Forrester, Canberra, A.C.T.	1957
Read, T. A., FSTC FRACI MAusIMM, 15 Chatfield Av., Balwyn, E8	1960
Rees, A. L. G., DSc PhD, C.S.I.R.O. Division of Chemical Physics, Box 4331, G.P.O., Melbourne, C1	1956
Reid, J. T., 'Sherwood', 3 Triggarron Av., Kew, E4	1954
Resch, C. E., BSc PhD, 16 Bouverie St, Carlton, N3	1957
Richardson, Mrs J. R., MA PhD, 16 Raven St, Kew, E4	1958
Rigby, J. F., 5 Banool St, Keiraville, N.S.W.	1953
Rowney, G., BSc, 4 Riddle St, Bentleigh, SE14	1952
Ryan, R. M., BA, National Museum of Victoria, Russell St, Melbourne, C1	1961
Sauve, N. B., 7 Mervyn Cr., Ivanhoe, N21	1955
Sayce, E. L., BSc, FInstP, 16 Maleela Av., Balwyn, E8	1924
Scott, A. R., BE, AMIE, 10 Verdant Av., Toorak, SE2	1958
Seeger, R. C., 56 Jenkins St, Northcote, N16	1946
Selby, B. A., BSc, ARACI, 19 Chesterfield Av., Malvern, SE4	1958
Simpson, H. P., 8 Knutsford St, Balwyn, E8	1948
Sinclair, A. Q., c/o Commonwealth Fertilisers and Chemicals Ltd, 65 William St, Melbourne, C1	1959
Skinner, G., LLB, 111 Charles St, Prahran, S1	1960
Slack-Smith, R. J., BSc, c/o Fisheries Dept, 108 Adelaide Terrace, Perth, W.A. ..	1960
Smith, L. H., MSc DPhil, FRACI, 36 Duke St, Kew, E4	1958
Somerset, H. B., MSc, MAIMM, c/o A.P.P.M. Ltd, 360 Collins St, Melbourne, C1 ..	1957
Specht, R. L., MSc PhD, Botany Dept, University, Parkville, N2	1961
Spencer-Jones, D., MSc PhD, 31 Wimmalee Rd, Balwyn, E8	1952
Spicer, P. O., 13 Riverside Av., N. Balwyn, E9	1946
Stevens, B. J. M., 117 Millswyn St, South Yarra, SE1	1961
Stylcs, D. F., BSc, AMIE Aust., 14 John St, Blackburn	1958
Sullivan, W., 37 Strathallan Rd, Macleod	1943
Sutton, P. R. N., DDS, LDS, 24 Wellington St, Brighton, S5	1959

Tattam, Assoc. Prof. C. M., PhD DSc, Geology Dept, University, Parkville, N2	1945
Taylor, D. J., BSc, 23 Westbourne St, Prahran East, S1	1961
Temple, P., 7 Monash St, Ascot Vale, W2	1962
den Tex, Prof. E., PhD <i>Leyden</i> , State University, Leyden, Netherlands	1952
Ternouth, S. T., BSc DipEd, 50 Hatfield St, N. Balwyn, E9	1957
Thomas, D. E., DSc, Mines Dept, Melbourne, C2	1929
Thomas, F. J. D., BSc (Hons), ARCS, I.C.I.A.N.Z. Biological Research Station, Croydon	1955
Thomas, G. A., BSc PhD, Geology Dept, University, Parkville, N2	1944
Thomas, H. F., PO Box 78, Irymple	1961
Thompson, G. D., AMIE <i>Aust.</i> HonMIBF <i>Lond.</i> , Royal Melbourne Institute of Technology, Latrobe St, Melbourne, C1	1959
Thompson, G. T., 43 Weybridge St, Surrey Hills, E10	1953
Thomson, D. F., OBE, DSc <i>Melb.</i> PhD <i>Cantab</i> DipAnthrop <i>Cantab & Sydney</i> , Anthropology Dept, University, Parkville, N2	1958
Thomson, J. A., MSc, Zoology Dept, University, Parkville, N2	1958
Thorn, W., MEE MIE <i>Aust.</i> , 132 Canterbury Rd, Canterbury, E7	1958
Thrower, L. B., MSc, 23 Laver St, Kew, E4	1961
Timeke, E. W., 15 Faircroft Av., Glen Iris, SE6	1950
Tindale, B., FRMS, Yarra Junction	1951
Townsend, Prof. S. L., MD MS, FRCS <i>Edin.</i> , Obstetrics and Gynaecology Dept, University, Parkville, N2	1951
Tudehope, N. A., BSc, 22 St James Av., Mont Albert, E10	1960
Turner, Prof. J. S., MA PhD MSc, FAA, University, Parkville, N2	1938
Tylee, A. F. E., BE BSc, 31 Wingan Ave, Camberwell, E6	1961
Tylee, A. N., Jindivick North	1951
Vale, W. H., 11 Edgar St, Brighton, S5	1961
Wadham, Prof. Sir Samuel M., MA LLD AgrDip, 220 Park St W., W. Brunswick, N12	1932
Wakefield, N. A., BSc, 30 Douglas St, Noble Park	1961
Wark, I. W., PhD DSc, FAA, C.S.I.R.O., 314 Albert St, E. Melb., C2	1961
Watson, J. E., 74 Nimmo St, Essendon, W5	1961
Weickhardt, L. W., MSc, FRACI, 125 Canterbury Rd, Canterbury, E7	1959
Wettenhall, H. N. B., MD BS, MRCP FRACP, 41 Spring St, Melbourne, C1	1959
White, Sir A. E. Rowden, CMG, MD, FRACP, 14 Parliament Pl., Melbourne, C2	1938
White, Prof. M. J. D., DSc <i>Lond.</i> , FRS FAA, Zoology Dept, University, Parkville, N2	1958
White, R. K., FIPAA, 360 Collins St, Melbourne, C1	1958
Whiting, R. G., BME, 7 Barkly Ter., Mitcham	1959
Wickens, T. W., 27 Narrak Rd, Balwyn, E8	1957
Wilcock, A. A., BSc BEd, Geography Dept, University, Parkville, N2	1934
Williams, W. D., BSc PhD, FZS, Monash University, Clayton	1961
Willis, A. G., MSc, Zoology Dept, University, Parkville, N2	1949
Wilson, D., BSc, 46 Hoddle St, Essendon, W5	1961
Wiltshire, A. R. L., CMG DSO MC VD, 35 Evans Ct, Toorak, SE2	1955
Wishart, R. M., MB ChB N.Z., FRACS FRMS, Flat 12, 7 College Pd., Kew, E4	1958
Woodburn, J. L. F., BA, Flat 2, 9 Corsewall Close, Hawthorn, E2	1958
Worcester, R. G., MD DGO, FRCS FRACS FRCOG, 106 North Rd, Brighton, S5	1958

COUNTRY MEMBERS

Adams, H. G. C., 'Danedite', Weerite	1945
Baldwin, J. G., BSc BAgSc, 33 Walnut Av., Mildura	1949
Bishop, J. J., BA, High School, Queenscliff	1950
Burn, R., 34 Autumn St, Geelong W.	1956
Casey, Mrs D. A., 'Murraba', Coldstream	1953
Condon, M. A., MSc, Bureau of Mineral Resources, Canberra, A.C.T.	1937
Conley, W. R., High School, Heathcote	1956
Corney, Mrs A. D., BSc, 17 Ratho St, New Town, T.	1945
Dawes, L. F., BSc, 43 Hopetoun Gr., Ivanhoe, N21	1954
Dickins, J. MacG., MSc PhD, Bureau of Mineral Resources, Canberra, A.C.T.	1952
Forrest, J. M., Metropolitan Farm, P.O., Werribee	1954
Glaessner, M. F., PhD DSc, FAA, Geology Dept, University of Adelaide, S.A.	1939
Hill, Prof. Dorothy, DSc PhD, FAA, Geology Dept, University of Queensland, St Lucia, Q.	1939

LIST OF MEMBERS

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Hope, G. B., BME, 'Carrical', Hermitage Rd, Newtown, Geelong	1918
Howe, Mrs A. W., BSc, 18 Devencourt St, South End, Mt Isa, Q.	1948
Kershaw, R. C., BSc, 'Manorama', c/o Lyetta P.O., W. Tamar, T.	1956
Lindholm, J. D. E., c/o High School, Shepparton	1952
McWhae, Mrs J. R. H., MSc, 262 St Georges Ter., Perth, W.A.	1948
Mack, G., BSc, Queensland Museum, Brisbane, Q.	1943
Massey, C. H., 11 Church St, Ashfield, N.S.W.	1957
Merigan, Janice E., BSc, 2 Minawa St, Cooma N., N.S.W.	1957
Murphy, H. D., Mornington	1950
Netherway, G. C., 606 Dana St, Ballarat	1958
Payne, T. E. N., 'Woodburn', Kilmore	1945
Schleiger, N. W., 32 Pryor St, Eltham	1949
Searle, S. S., Metropolitan Farm, P.O., Werribee	1954
Trebilecock, Lieut-Colonel R. E., MC, Wellington St, Kerang	1921
Yates, H., MSc, School of Mines, Ballarat	1943

ASSOCIATES

Autry, W. C., BSc, Senior Mess, Woomera, S.A.	1957
Baker, A. A., 53 Carlisle St, Preston, N18	1946
Bell, G., BSc, 13 Kent Rd, Surrey Hills, E10	1955
Bird, R. G., 'Hoana', Saltpan Bay, Prince Alfred Pde, Newport, Sydney, N.S.W.	1962
Bock, P. E., BSc, 78 Hickford St, Reservoir, N19	1957
Bollen, P. W., BSc, 60 Mann Ter., N. Adelaide, S.A.	1957
Bowler, J. M., MSc, Geology Dept, University, Parkville, N2	1960
Brunn, Mrs. T. H., 605 Malvern Rd, Toorak, SE2	1960
Burns, D., 11 Robertson St, Colac	1960
Butler, L. S. G., 3 Los Angeles Ct, St Kilda, S2	1929
Buttery, S. H., 146 Highfield Rd, Camberwell, E6	1952
Carr, Mrs D. J., MSc, Queen's University, Belfast, N. Ireland	1937
Carter, A. N., MSc PhD, 8 Scott St, Maroubra Bay, N.S.W.	1947
Clarke, W. G., BSc DipEd, 67 Willis St, Hampton, S7	1957
Clifford, H. T., MSc PhD, Botany Dept, University of Queensland, St Lucia, Q.	1949
Coats, R. P., BSc, South Australian Dept of Mines, 169 Rundle St, Adelaide, S.A.	1951
Cobbett, A. M., Oxford Close, Moorabbin, S20	1951
Cochrane, G. W., MSc, Sura Dungun, Trennganu, Malaya	1945
Cormack, M. G., c/o Lower Crawford Private Bag 39, Heywood	1960
Court, A. B., MSc, National Herbarium, Royal Botanic Gardens, S. Yarra, SE1	1949
Douglas, J. G., BSc, 76 Sunhill Rd, Mt Waverley	1957
Ducker, Mrs S. C., 36 Percy St, Balwyn, E8	1959
Elford, F. G., BSc BED, 76 New St, Brighton, S5	1929
English, J. R., 302 Lower Heidelberg Rd, E. Ivanhoe, N21	1956
Esplan, W. A., BSc, 37 Barnes Av., Burwood, E13	1951
Finlay, Miss C. F., BSc, Geology Dept, University, Parkville, N2	1950
Fisher, Eileen E., PhD, 1 Balwyn Rd, Canterbury, E7	1949
Frostick, A. C., 9 Pentland St, N. Williamstown, W16	1933
Gale, J. C., 154 Mont Albert Rd, Canterbury, E7	1959
Hewett, D. C., BSc DipEd, 77 Agg St, Newport, W15	1959
Holdaway, E. A., BSc, 3 Patricia St, Box Hill, E11	1957
Hounslow, A. W., BSc, 28 Georgiana St, Sandringham, S8	1958
Johns, M. W., BSc, 355 Upper Heidelberg Rd, Ivanhoe, N21	1958
Kenley, P. R., BSc, Flat 3, 'Warleigh Court', 26 Warleigh Gr., Brighton, S5	1948
Lawrence, C. R., BSc, 3 Wright St, Bentleigh, SE14	1958
Learmonth, A. P., S.E.C., 658 Church St, Richmond, E1	1955
Learmonth, J. C., Flat 4, 117 Caroline St, S. Yarra, SE1	1959
Lord, E. E., G.P.O. Box 5278, Melbourne, C1	1950
McLennan, Assoc. Prof. Ethel, DSc, Botany Dept, University, Parkville, N2	1915
Marsden, M. A. H., 17 Oak St, Beaumaris, S10	1952
Matthaei, Mrs G., 146 Gatehouse St, Parkville, N2	1959
Mitchell, S. R., 22 Grosvenor St, Abbotsford, N9	1945

Moir, Mrs Marion M., MA DipEd, 434 Elgar Rd, Box Hill, E11	..	..	..	..	1960
Moore, B. R., BSc, Peter St, Eltham	..	..	..	..	1957
Morris, P. F., 6 Mandeville Cr., Toorak, SE2	..	..	..	..	1921
Neilson, J. L., 1 Fordham Av., Camberwell, E6	..	..	..	..	1952
Nicholas, T., Bureau of Mineral Resources, Canberra, A.C.T.	..	..	..	..	1958
Passioura, J. B., Agriculture Dept, University, Parkville, N2	..	..	..	..	1961
Philip, Mrs G. M., BSc, Sedgwick Museum, Cambridge, England	..	..	..	..	1957
Pinches, Mrs M., 140 Churehill Highway, Braybrook, W19	..	..	..	..	1943
Pretty, R. B., MSc, Private Bag, Cobargo, N.S.W.	..	..	..	..	1922
Pringle, J. V., 422 Waverley Rd, E. Malvern, SE5	..	..	..	..	1961
Rash, K. E., 75 Humffray St, S. Ballarat	..	..	..	..	1960
Rawlins, R. J., BSc, c/o Post Office, Cloncurry, Q.	..	..	..	..	1957
Reed, K. J., Dept of Geology, McGraw Hall, Cornell University, Ithaca, N.Y., U.S.A.	..	..	..	..	1958
Rimington, K. N., BSc, 15 Yuille St, Brighton, S5	..	..	..	..	1948
Shaw, H., 18 Normanby Rd, E. Bentleigh, SE15	..	..	..	..	1956
Sherrard, Mrs H. M., MSc, 43 Robertson Rd, Centennial Park, N.S.W.	..	..	..	..	1918
Simpson, B., 3 Knufford St, Balwyn, E8	..	..	..	..	1959
Singleton, O. P., MSc PhD, Geology Dept, University, Parkville, N2	..	..	..	..	1943
Sinnott, P. J., 17 Normdale Rd, E. Bentleigh, SE15	..	..	..	..	1959
Stewart, A. J., MSc, Havelock House, Northbourne Ave, Canberra, A.C.T.	..	..	..	..	1961
Stubbs, D., 2 Coleridge St, Elwood, S3	..	..	..	..	1960
Talent, J. A., MSc PhD, Mines Dept, E. Melbourne, C2	..	..	..	..	1955
Valiullah, M., MSc, Geology Dept, University, Parkville, N2	..	..	..	..	1962
Vasey, G. H., BCE, University, Parkville, N2	..	..	..	..	1936
Walker, A. L., Chemistry Dept, University, Parkville, N2	..	..	..	..	1961
Watts, H. A., 15 Tower Hill Rd, Glen Iris, SE6	..	..	..	..	1954
White, O. L., BSc, Dept of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada	..	..	..	..	1955
Whitehead, Mrs R., 45 Whitehead St, Whyalla, S.A.	..	..	..	..	1942
Wilkins, R. W. T., MSc, Geology Dept, University, Parkville, N2	..	..	..	..	1961
Williams, G. E., BSc, 7 Derby St, Camberwell, E6	..	..	..	..	1962
Wymond, A. P., MSc, C.S.I.R.O. Division of Forest Products, P.O. Box 18, S. Melbourne, SC4	..	..	..	..	1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1961

The President and Council present to members of the Society the Annual Report and Financial Statement for the year 1961.

The following meetings of the Society were held:

March 9—ANNUAL MEETING. The following office-bearers were elected: *President*, Dr R. R. Garran; *Vice-Presidents*, Mr R. T. M. Pescott, Dr D. E. Thomas; *Honorary Treasurer*, Mr L. Adams; *Honorary Secretary*, Mr E. D. Gill; *Honorary Librarian*, Assoc. Professor C. M. Tattam. The following members of Council were elected: Mr V. G. Anderson, Mr W. Baragwanath, Mr D. A. Casey, Captain J. K. Davis, Professor J. S. Turner, Assoc. Professor G. W. Leeper (for two years); Mr H. C. Chipman, Dr C. Resch (for one year). The following members of Council continued in office: Mr J. H. Chinner, Dr C. M. Focken, Dr F. L. Stillwell, Mr A. G. Willis. It was decided to deal with the Annual Report and Financial Statement for 1960 and with the alteration of Laws at a later meeting. Upon conclusion of the Annual Meeting an ORDINARY MEETING was held in the form of a Symposium on Space Exploration. Dr V. D. Hopper dealt with the physical aspects and Dr J. C. Lane with the human aspects. A film on 'The Echo II Satellite' was screened.

April 13—LECTURE: 'Forensic Science in Victoria' by Mr R. C. Bayly, followed by comment on legal aspects by the Hon. Sir Arthur Dean. Mr N. C. Manning opened the discussion.

May 11—SPECIAL GENERAL MEETING. Alterations to the Laws were adopted providing for the deletion of the categories of Corresponding Member and Country Member (although the present list to remain), and for an Honorary Assistant Secretary. An ORDINARY MEETING followed, consisting of a Symposium on 'Recent field work of the Australian National Antarctic Research Expeditions'. The speakers were Mr P. G. Law, Mr I. R. McLeod and Dr U. Radok.

June 8—The Annual Report and Financial Statement were adopted. Dr A. C. McLaren was elected Assistant Secretary. LECTURE: 'Exploitation of Australia's mineral resources' by Dr I. W. Wark.

June 15—SPECIAL LECTURE in co-operation with the University of Melbourne: 'The Tertiary mammals from the Tirari Desert' by Professor R. A. Stirton, University of California.

July 13—PRESENTATION of Verco Medal on behalf of the Royal Society of S.A. to Dr R. L. Specht, and first award of this Society's Research Medal to Dr G. Baker.

RESEARCH PAPERS:

'The dune succession at Corner Inlet, Victoria' by Professor J. S. Turner, Mrs S. G. M. Carr and Dr E. C. F. Bird.

'A disease of pelargoniums caused by *Xanthomonas pelargonii*' by Dr Rose Mushin and Mr H. R. Smith.

'The occurrence of *Otozamites* in SE. Victoria' by Mr J. G. Douglas.

'Granite Islands of SE. Victoria as a seabird habitat' by Dr Mary E. Gillham.

'Deltas of the Gippsland Lakes, Victoria' by Dr E. C. F. Bird.

'The salts of Lake Linga, Victoria' by Dr R. R. Cane.

'Contact metamorphism at Big Hill, Bendigo, Victoria' by Dr F. C. Beavis.

'Notes on the geology of the Lorne district' by the late Dr A. B. Edwards.

August 10—LECTURE: 'The Hill Kangaroo (*Macropus robustus*) in NW. Australia' by Mr E. H. M. Ealey.

September 14—VICTORIAN HIGH PLAINS SYMPOSIUM:

3.00 p.m. Geology, pedology, meteorology and hydrology.

5.30 p.m. Anthropology and zoology.

8.00 p.m. Ecology. Total environment and utilization.

Mr A. B. Costin of Canberra was the Guest Speaker of the Society at this Symposium.

October 12—LECTURE: 'Population dynamics of body cells' by Professor Sir Macfarlane Burnet.

November 9—SOIREE: reception, exhibits, colour slides of Australian animals in their natural state, scientific movie films. A live Leadbeater's Possum, a species previously thought extinct, was exhibited by the Fisheries and Wildlife Department.

December 14—LECTURE: 'The basic problems of world food supply in the next quarter century' by Professor Sir Samuel Wadham. The following paper was read by title only: 'Some Cretaceous and Tertiary microplankton of uncertain affinity from Australia' by Dr Isabel C. Cookson and Professor A. Eisenack.

On November 27, a CONFERENCE of specialists was held in the Society's Hall with Professor F. E. Zeuner, Professor of Environmental Archaeology, University of London.

The number of members at 31 December 1961 was: Honorary Members 2, Life Members 17, Members 277, Country Members 70, Associates 28, making a total of 394. The membership of the Society has doubled since the war.

During the year 2,637 volumes and parts were added to the library.

Attendances at Council meetings were: Adams 9, Anderson 8, Baragwanath 10, Casey 2, Chinner 5, Chipman 7, Davis 7, Focken 8, Garran 9, Gill 10, Leeper 9, McLaren 8, Pescott 2, Resch 6, Stillwell 10, Tattam 10, Thomas 6, Turner 2, Willis 3.

The Society deeply regrets the loss during the year of an Honorary Member.

ALBERT CHERBURY DAVID RIVETT, KCMG, MA DSC, FRs FAA, was born in Tasmania and died in Sydney on 1 April 1961 at the age of 75. Educated at Wesley College and at the University of Melbourne, he was awarded a Rhodes Scholarship and studied at Oxford with N. V. Sidgwick and later at the Nobel Institute, Stockholm, with S. Arrhenius. There he developed his special interest in physical

chemistry, which led to his researches into the phase rule and its application. In World War I he was engaged in Australia and in England on problems of chemical warfare and munitions production. He then returned to the University of Melbourne as Lecturer, and later Associate Professor. In 1924 he succeeded his mentor, Sir David Orme Masson, as Professor of Chemistry. In 1927 he was appointed Chief Executive Officer of the newly created Council for Scientific and Industrial Research, and in 1945 he became its Chairman. When C.S.I.R. was reorganized in 1949 he was the first Chairman of the Advisory Council. It is very largely to him that C.S.I.R.O. owes its present standing. He was knighted in 1935. He served as President of A.N.Z.A.A.S. in 1937-39, as General President of the Royal Australian Chemical Institute in 1939-40 and again in 1948-49, and as President of the Society of Chemical Industry in 1949-50. He was elected as Fellow of the Royal Society in 1941 and was a Foundation Member of the Australian Academy of Science. He had been a Member of the Royal Society of Victoria since 1911, and was elected to Honorary Membership in 1959.

ANNUAL REPORT

TREASURER'S REPORT

The expenditure exceeded receipts by £500/17/9, although rents and subscriptions were the highest ever collected. £100 was invested during the year.

Three separate parts and volumes were published during the year, and this, together with the steadily increasing cost of printing accounted for the major expenditure.

Repairs and maintenance were kept rigidly to a minimum but with a building 102 years old, increased repairs must be expected.

The Society expresses its appreciation to the State Government for its Grant of £500, and also to the University of Melbourne for its assistance in the publication of papers.

SUMMARY FOR THE YEAR ENDING 31 DECEMBER 1961

Total Receipts	£3,977 11 9
Balance from 1960	608 7 9
	<hr/>
	£4,585 19 6
Expenditure	4,478 9 6
	<hr/>
Balance at Bank 31/12/1961	£107 10 0
	<hr/> <hr/>

INVESTMENTS HELD AS AT 31 DECEMBER 1961

Australian Guarantee Corporation Limited	
7% Debenture Stock	£1,000 0 0
Australian Aluminium Company Limited	
7% Debenture Stock	800 0 0
Bitumen and Oil	
8% Notes	100 0 0
	<hr/>
	£1,900 0 0
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FINANCIAL STATEMENT FOR YEAR ENDING 31 DECEMBER 1961

RECEIPTS				EXPENDITURE			
Balance at Bank 1/1/61	..	..	£608 7 9	Salaries—	..	..	£817 15 7
Subscriptions	..	..	1,230 3 0	Assistant Editor	..	..	2,026 16 5
Rents	..	..	1,037 19 0	Assistant Librarian	..	..	159 15 8
Sale of Publications	..	..	364 11 5	Clerical	..	..	48 9 11
Interest	..	..	413 2 1	Hallkeeping	..	..	47 13 6
Grants and Donations	..	..		Printing Proceedings	..	..	270 14 0
The Government of Victoria	..	£500 0 0		Stationery	..	..	742 0 11
University of Melbourne	..	91 10 0	591 10 0	Telephone	..	..
Refunds—				Rates	..	..
Hallkeeping	..	£120 10 0		Electricity	..	..
Telephone	..	6 3 0		Repairs and Maintenance	..	..
R.C.O.G.	..	179 15 2		Sundry Purchases—	..	..
Sundries	..	33 18 1	340 6 3	Index	..	..
				Shares	..	..	£6 0 0
				Stamp Duty	..	..	100 0 0
				Insurance	..	..	55 19 4
				Postage	..	..	161 19 10
				War Memorial Library Trust	..	..	113 16 0
				Balance at Bank 31/12/1961	..	..	89 7 8
							107 10 0
							£4,585 19 6

LIONEL ADAMS, *Hon. Treasurer*

Audited and found correct

T. M. CHERRY } *Hon.*
CARL RESCH } *Auditors*

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